Knowledge is an Important Aspect of COVID-19 Vaccine Hesitancy

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Vaccine hesitancy was an ongoing issue during the COVID-19 pandemic. We recruited 620 adults for an online questionnaire to assess the influence of various factors on vaccine hesitancy. Five pre-existing scales were used to measure vaccine knowledge, attitudes to doctors and medicine, vaccine conspiracy belief, perception of COVID-19 as a threat, and vaccine hesitancy. We found that low vaccine knowledge was the strongest predictor for hesitancy. We also collected information about age, gender and vaccine status (fully vaccinated, with or without booster, partially vaccinated, not vaccinated). There were no age or gender effects, but we found significant trends between vaccination status and knowledge, attitudes, conspiracy belief, and hesitancy.

Since COVID-19 was declared a global pandemic (Cucionotta & Vanelli, 2020), there has been success in developing effective vaccines and distributing them around the world (World Health Organization, 2022). However, a significant number of people are not vaccinated (Buscemi et al., 2023, Gravelle et al., 2022). Research has shown that *vaccine hesitancy* is responsible for the refusal and delay in acceptance of vaccines – and it is "on a continuum between those who accept all vaccines with no doubts, to complete refusal with no doubts, with vaccine hesitant individuals the heterogenous group between these two extremes" (MacDonald et al., 2015, pp. 4161-4162). There are many potential causes that feed into vaccine hesitancy (Cooper et al., 2021; Dubé at al., 2014; Larson et al., 2014; MacDonald et al., 2015). Here, we focus on four predictive factors: vaccine knowledge, attitudes to doctors and medicine, vaccine conspiracy belief, and perception of COVID-19 as a threat. Note that none of our chosen factors relate to an individual's inherent personality, which is justifiable given that previous studies have found no influence of personality traits (e.g. Bogg et al., 2023).

On the first factor, vaccine knowledge, research has shown that both knowledge and misconceptions play a significant role in vaccine hesitancy (Gust et al., 2005; Luthy et al., 2012). Research by Zingg and

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Siegrist (2012) revealed that misconceptions about vaccines in society are common and individuals' level of knowledge about vaccines affects their decisions to vaccinate themselves and their children. A more recent study (Abebe et al., 2021) concluded good knowledge on COVID-19 to be a determinate factor for accepting a COVID-19 vaccine. On the second factor, attitudes to doctors and medicine, previous studies have found that individuals who have a negative attitude towards medicine are less likely to follow medical instructions (Conroy et al., 2002; Marteau, 1990). Mistrust in medicine and doctors have been linked to lower compliance with COVID-19 rules and less enthusiasm for a vaccine (Freeman et al., 2021). On the third factor, conspiracies, there is widespread belief in conspiracy theories about vaccines, and these beliefs can influence individuals' health decisions (Bruder et al., 2013; Cobos Muñoz et al., 2015; Craciun & Baban, 2012). Research by Shapiro et al. (2016) has shown a link between general conspiracy beliefs and vaccine-specific conspiracy beliefs. These conspiracies give rise to enduring anti-vaccination movements (Kalichman & Eaton, 2023; Martinez-Berman et al., 2020). On the fourth factor, perception of COVID-19 as a threat, studies have found that when individuals perceive a higher level of threat, they are more likely to support interventions that reduce that threat, such as vaccinations (Sheeran et al., 2014). Early research during the COVID-19 pandemic suggested that individuals who saw the deadly consequences of the virus and viewed it as a threat were more willing to get vaccinated once vaccines became available (Dror et al., 2020). Finally, we looked at gender differences. A study by Dodd et al. (2022) found gender differences in perceived risk of COVID-19, with females scoring lower on the scale. Additionally, a more recent study by Liu and Li (2021) found that only a very low minority of females develop hesitancy due to perceived risk of COVID-19.

In our study, we investigated the reasons for vaccine hesitancy by comparing scores on a vaccine hesitancy scale (Rodriguez et al., 2022) against scales that measure vaccine knowledge (Zingg & Siegrist, 2012), attitudes to doctors and medicine (Fridman et al., 2021; Marteau, 1990), belief in conspiracy theories (Shapiro et al., 2016), and perception of COVID-19 as a threat (Dror et al., 2020). Based on previous findings, we predicted that individuals with high vaccine hesitancy likely would have higher levels of distrust, lower levels of perceiving a threat, poorer vaccine knowledge, and would be more prone to believing conspiracy theories. Additionally, we analysed the variables of age, gender, and vaccine status (fully vaccinated with booster, fully vaccinated without booster, partially vaccinated, not vaccinated).

METHOD

Participants

Our study involved 620 participants with complete responses (422 female, 193 male, 5 other), mean age 27.35 years (*SD* = 9.71, range 18–74), where 335 were fully vaccinated with a booster, 194 were fully vaccinated without a booster, 25 were partially vaccinated, and 66 were not vaccinated. Information about geographic location was not collected. Most of our sample was recruited through e-mail and social media. Approximately 7% of our sample consisted of undergraduate psychology students from a London UK university participating for course credit. No other incentives were offered. We screened the data for speed of response and deleted responses which did not meet the minimum response time. We also identified one multivariate outlier using Mahalanobis Distance and decided to remove it from the data. Our study was approved by our departmental Research Ethics Committee.

Materials

Our online survey (Qualtrics) consisted of five scales: (1) *Vaccine Knowledge Scale* (Zingg & Siegrist, 2012), (2) *Attitudes to Doctors and Medicine Scale* (Marteau, 1990), (3) *Vaccine Conspiracy Belief Scale* (Shapiro et al., 2016), (4) *Perception of COVID-19 as a Threat Scale* (Fridman et al., 2021), and (5) *Vaccine Hesitancy Scale* (Rodriguez et al., 2022). Some questions from the scales were omitted in our study. The list of questions we used is viewable online at https://doi.org/10.6084/m9.figshare.24411805. All reported Cronbach's alphas were calculated using the current sample.

Vaccine Knowledge Scale We used a scale designed by Zingg and Siegrist (2012) to measure general knowledge about vaccinations (α = .87). We used 10 items from the original scale with a reported Loevinger's coefficient of $H = .45$ and reliability of $\rho = .79$. Vaccine knowledge was measured using a five-point Likert scale ranging from 1 (definitely true) to 5 (definitely false). Higher scores indicated better vaccine knowledge.

Attitudes to Doctors and Medicine Scale We used a scale designed by Marteau (1990) to measure attitudes to doctors and medicine. We used 15 items from the original scale (α = .73). Attitudes to doctors and medicine were measured using a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Higher scores indicated more positive attitudes towards doctors and medicine.

Vaccine Conspiracy Belief Scale We used a 6-item scale developed by Shapiro et al. (2016), α = .88. As reported by Shapiro et al. (2016), the item-total correlation coefficients for this scale ranged between 0.77

and 0.82. Vaccine conspiracy belief was measured using a five-point Likert scale ranging from 1 (definitely true) to 5 (definitely false). Higher scores indicated higher conspiracist thinking.

Perception of COVID-19 as a Threat Scale We used a recently designed scale designed by Fridman et al. (2021). We used 6 items from the composite measure (α = .50). Perception of COVID-19 was measured using a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Higher scores indicated a higher perception of threat from COVID-19 infection.

Vaccine Hesitancy Scale Here, we used a 10-item scale (α = .91) adapted to COVID-19 by Rodriguez et al. (2021) using the vaccine hesitancy scale developed by Shapiro et al. (2018). Vaccine hesitation was measured using a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Higher scores indicated higher vaccine hesitancy.

Procedure

Data were collected from March to July 2022 (see survey at https://doi.org/10.6084/m9.figshare.24411805). The first survey page consisted of an information/consent form, followed by questions about age, gender, and vaccination status. This was followed by the aforementioned scales where participants indicated their agreement with a set of statements along Likert scales, and a debriefing page at the end.

Data Analytic Plan

We had four main predictors as independent variables (to save space, referred to below as "knowledge", "attitudes", "conspiracy", and "threat"), and the dependent variable was vaccine hesitancy. The datafile is available online (Creative Commons Attribution 4.0) at https://doi.org/10.6084/m9.figshare.23676675. Incomplete responses were removed from the dataset prior to analysis. As shown below, we employed three main analyses: (1) correlations between main variables, (2) hierarchical regression to assess the impact of the dependent variables on vaccine hesitancy, and (3) non-parametric tests to compare vaccine hesitancy according to whether the participant had been vaccinated and to what extent.

RESULTS

The main aim of our analysis was to determine the extent to which the four main predictors explain the variance in the vaccine hesitancy scores. Descriptive statistics for all five scales are shown in Table 1 (left column). We first looked at correlations between the four covariates and vaccine hesitancy. As shown in Table 2, every variable is correlated with each other.

Table 1: Descriptive statistics (Mean, SD) for all scales, and comparison of scores according to vaccination status

Results for each scale (n = 620)	[A]Fully vacc with booster (n = 335)	[B]Fully vacc without booster (n = 194)	[C]Partially vacc (n = 25)	[D]Not vacc (n = 66)
Knowledge[a] 35.69 (7.74)	38.04 (7.15)	35.04 (6.83)	32.64 (6.81)	26.83 (6.28)
Threat[b] 20.38 (6.88)	20.35 (3.77)	20.30 (3.68)	19.92 (3.29)	20.58 (3.63)
Attitudes[c] 49.11 (7.42)	50.66 (7.22)	48.40 (6.85)	45.76 (6.68)	44.58 (7.84)
Conspiracy[d] 15.59 (5.40)	14.04 (5.40)	15.97 (4.31)	18.76 (4.27)	21.15 (4.24)
Hesitancy[e] 23.13 (8.24)	20.40 (6.70)	23.07 (7.10)	29.08 (6.02)	34.85 (7.74)

Notes: Jonckheere-Terpstra trend tests, two-tailed (see row labels): (a.) T_{JT} = 34542.00, z = -9.863, p < .001; (b.) T_{JT} = 59680.00, z = -.264, p = .792; (c.) T_{JT} = 43002.00, z = 6.212, p < .001; (d.) T_{JT} = 79823.50, z = 9.694, p < .001, (e.) T_{JT} = 82858.00, z = 10.995, p < .001. Mann-Whitney tests, pairwise comparisons between A, B, C, D (see column labels): all significant at p < .001 except all threat comparisons; A-C attitudes, p = .003; B-C attitudes, knowledge, *ns*, conspiracy, p = .005; and C-D attitudes, *ns*, conspiracy, p = .016.

Table 2 Correlations (Spearman's rho) between four covariates and vaccine hesitancy (n = 620).

Variable	Threat	Attitudes	Conspiracy	Hesitancy
Knowledge	.256**	.537**	-.803**	-.784**
Threat	-	.095*	-.235**	-.134**
Attitudes	-	-	-.532**	-.594**
Conspiracy	-	-	-	.720**

* p < .05, ** p < .001.

To explore these relationships further, we conducted a hierarchical multiple regression, controlling for age, gender, and vaccination status (the latter which can be considered an ordinal variable). Thus, age and gender were used in step 1, vaccination status was added in step 2, and the four main predictors were added in step 3. As shown in Table 3, there was a significant increase in R^2 in step 2 ($F = 235.133$, $df = 4, 506$, $p < .001$) and in step 3 ($F = 315.099$, $df = 4, 506$, $p < .001$). Age was a significant predictor in the first step, but not in the following steps. Vaccination status was significant in steps 2-3, but had a diminished influence in step 3, alongside the four main predictors, all of which were significant. Of these predictors, *knowledge* had the largest effect. Specifically, there was an inverse relationship, where for every one-unit increase in vaccine knowledge, there was a decrease of –0.536 units in vaccine hesitancy. Other predictors had a weaker effect, with the threat predictor being the weakest ($\beta = .058$).

Table 3. Hierarchical multiple regression, with vaccine hesitancy as a dependent variable, and using four main predictors, controlling for age, gender, and vaccination status.

		B	*SE*	*B*
Step 1				
	Constant	24.710	1.564	
	Age	-.094	.034	-.111*
	Gender	.585	.714	
Step 2				
	Constant	14.726	1.484	
	Age	-.025	.029	
	Gender	.792	.608	
	Vaccination status	4.538	.298	.529**
Step 3				
	Constant	44.339	3.063	
	Age	.033	.019	
	Gender	.067	.397	
	Vaccination status	1.724	.215	.201**
	Knowledge	-.576	.041	-.542**
	Attitudes	-.215	.031	-.193**
	Conspiracy	.147	.058	.097*
	Threat	.129	.052	.058*

Note. $R^2 = .012$ for Step 1: $\Delta R^2 = .286$ for Step 2 (ps < .001); $\Delta R^2 = .706$ for Step 3 (ps < .001). * $p < .05$, ** $p < .001$. For this analysis, gender was limited to male/female ($n = 615$).

We also examined the possibility of multicollinearity but found that VIF scores were not high enough to necessitate corrective measures (VIF for attitudes, threat, and vaccination status were low at 1.582, 1.122, and 1.305, respectively; and a bit higher for conspiracy and knowledge, at 3.061 and 3.123, respectively). Using the skewness statistic, we found that four main predictors were not skewed (skewness scores within +0.1/-0.1) – but that the vaccine hesitancy score was moderately skewed (.595, SE = .118). This suggests that the truly hesitant respondents were in a minority in our sample. Although our dependent variable (hesitancy) deviated from normality (Shapiro- Wilk, $W = .964$, $df = 620$, $p < .001$), the parametric test (hierarchical regression) was appropriate given the large sample size, and, from visual inspection of the Q-Q plot (Figure 1) showing that the distribution was approximately normal.

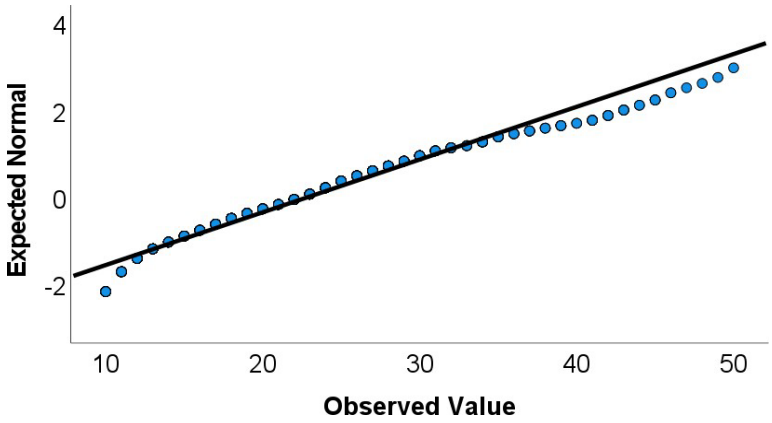

Figure 1: Normal Q-Q plot of vaccine hesitancy scores

Finally, we investigated the effect of vaccine status in more detail, comparing its effect on vaccine hesitancy and for each predictor separately. Table 1 displays each category of vaccination and the corresponding scores in vaccine hesitancy. Reading from left to right, there is a clear pattern in each row (except for threat), where columns follow an ascending or descending order. In the knowledge row,

for example, the score is descending A > B > C > D (38.04, 35.04, 32.64, 26.83) as the categories move from fully vaccinated with booster (A) to not vaccinated (D). Using the Jonckheere-Terpstra test, we found that these apparent trends were significant for each row, except for threats (see Table 1 notes). We also made pairwise comparisons, using the Mann-Whitney test, between every category of vaccination status and every scale (see Table 1 notes). Here, we found that most differences were significant (with the exception of threat, where none were significant).

DISCUSSION

Firstly, similar to findings by Abebe et al. (2021) we found that vaccine knowledge was the strongest covariate with vaccine hesitancy, congruent with findings from Zingg and Siegrist (2012) who found that individuals who had more knowledge about vaccines were more likely to get vaccinated, compared to those who had less knowledge. Other covariates were significant but had smaller effect sizes. Secondly, we found a relationship between negative attitudes towards doctors and medicine and vaccine hesitancy. This could be because people who have negative attitudes towards medicine are less likely to follow medical advice (Conroy et al., 2002; Marteau, 1990). This suggests that people who have a general mistrust of medicine and doctors are more likely to be hesitant about getting COVID-19 vaccines. Thirdly, we found a relationship between vaccine conspiracy beliefs and vaccine hesitancy. Given that conspiracist thinking influences people's decisions about their health (Bruder et al., 2013; Martinez-Berman et al., 2020) we could infer that people who believe in vaccine conspiracies are more likely to be hesitant or refuse vaccines. This likely applies to COVID-19 vaccines as well, with individuals who believe in COVID-19-related conspiracies being more likely to reject the vaccine. Additionally, a recent study (Enders et al., 2022) found suggestive evidence that COVID-19 conspiracy beliefs – that which leads to hesitancy and refusal – is likely the product of a person's general conspiracy-believing mindset (which itself is predicated on a person's psychological, political, and social motivations). Fourthly, we found a relationship between perception of COVID-19 as a threat and vaccine hesitancy. This is consistent with a previous study by Dror et al. (2020) who found that individuals who viewed COVID-19 as a threat were more willing to get vaccinated. However, opposite to the findings of gender differences in perceived risk of COVID-19 by Dodd et al. (2022) and Liu and Li (2021) we found no gender or age differences in our study.

We also found that vaccination status was an important factor, although we cannot presume a straightforward relationship between hesitancy and status (cf. Enders et al., 2022; MacDonald et al., 2015). For example, it might be true that, after someone gets vaccinated (perhaps reluctantly), that person's hesitancy actually diminishes afterwards (because the putative ill effects never arose). Our study cannot disentangle this causality. This is because our research design was associational, which did not allow us to directly infer cause-and-effect. That said, it is doubtless that vaccination status is important in our results. As shown above, it was a significant predictor in our hierarchical regression, and there were significant trends showing that vaccination status co-varies with most variables. The independent variable which showed the least effect was threat. There was no significant trend for threat (Table 1), and it had the weakest effect in the regression (Table 3). The implication is that *all* of our groups felt some level of threat. However, we should note a limitation in our sample here: there were uneven samples sizes between the different categories of vaccination status (see Table 1), which is a potential confound because it means we likely sampled too few people who are truly vaccine hesitant. In our defense, we have a similar proportion of unvaccinated respondents in our study (approximately 10%) as that found in other studies (e.g., Gravelle et al., 2022, who also had approximately 10%; but, also see Buscemi et al., 2023, who recruited participants through a clinic and obtained one-third unvaccinated respondents). It is possible that online surveys are generally less effective than other methods in reaching truly hesitant populations. In a study of social media posts, in contrast, Fieselmann et al. (2022) obtained a figure of 30% not wanting to be vaccinated. Another limitation of our study is the self-report methodology. It has long been known that, for self-report scales, we are forced to interpret the responses through the distorting lens of the respondent's self-assessment (Aftanas, 1988). Furthermore, responses could be influenced by social desirability. Given the public shaming that occurs on social media involving COVID-19 vaccination (van Poucke, 2023), some respondents may have felt cautious in expressing their true opinions. Another issue worth mentioning is that our choice of questionnaire might have influenced the pattern of results. There are numerous alternatives in the literature that we might have used instead. For example, for vaccine hesitancy, we might have used Freeman et al. (2021) instead of Rodriguez et al. (2021); for conspiracy beliefs, we might have used Bruder et al. (2013) instead of Shapiro et al. (2016). We might have used the medical mistrust index (cited in Buscemi et al., 2023) instead of Marteau (1990). We acknowledge a little bit of arbitrariness in our

choice of scales, but we did choose scales that appeared well supported in the literature. That stated, low reliability on the *Perception of COVID-19 as a Threat Scale* is a limiting factor. Another important issue is the timing of the survey, which could have had an effect on how participants responded. Since the data collection took place between March 2022 and July 2022, we had passed the peak of the pandemic and lockdowns. At the time, the initial threat of COVID-19 had passed, and therefore the results might be only relevant to the specific period of time only.

There have been numerous studies of vaccine hesitancy in recent years (Buscemi et al., 2023; Martinez-Berman et al., 2020). The results of our small study are broadly consistent with other studies on the topic of vaccine hesitancy. Overall, we conjecture that the level of a person's vaccine knowledge is the most important driver of vaccine hesitancy. As previous authors have said (e.g., Abebe et al., 2021; Fieselmann et al., 2013), it seems essential that public information on vaccines be available, relatable, and digestible by the public. That said, it is important to put the role of "knowledge" in context. For example, a number of studies (Bogg et al., 2023; Buscemi et al., 2022; Cobos Muñoz et al., 2015; Cooper et al., 2021; Dodd et al., 2022; Dubé et al., 2014; Fridman et al., 2021; Liu & Li, 2021; Enders et al., 2022; Larson et al., 2014) suggest that a person's political identity (e.g. U.S. Republican, Democrat), mixed in with demographic factors (e.g. gender, ethnicity, religion), have a strong influence on how public vaccine information is processed (e.g. whether it is believed at all), and this, in turn, mediates the extent of vaccine hesitancy and refusal. It may be true that poor communication about vaccines is detrimental, but it is not necessarily true that good communication by itself will solve the problem of hesitancy (MacDonald et al., 2015). Clearly, those involved in educating the public need to tailor their messages to accommodate the perspectives and biases of diverse audiences (Freeman et al., 2021; Kalichman & Eaton, 2023).

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