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When and why do people change their minds in favor of vaccination? Longitudinal analyses of switching COVID-19 vaccination preferences

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Abstract

Background Vaccinations are a cornerstone of public health. However, reluctance to accepting vaccines is common. Using longitudinal data, we investigated which individual and contextual factors were associated with switching preferences from initial hesitancy or unwillingness toward acceptance of a first COVID-19 vaccination.

Methods 12,512 participants of a Dutch cohort study who initially indicated being hesitant or unwilling to get vaccinated were included (December 2020–June 2022). Cox regression was used to determine what sociodemographic factors (e.g., age), vaccination-specific beliefs (e.g., perceived efficacy) and contextual factors (e.g., stringency of COVID-19 measures) were associated with switching toward getting vaccinated. Analyses were stratified into (1) the active campaign phase (over time more people became eligible for vaccination), versus (2) the residual phase (everyone was eligible and could still get vaccinated).

Results Over time, 86% of initially hesitant and 34% of initially unwilling participants got vaccinated or intended to do so. Switching was less likely for people aged 40-54y (adjusted hazard ratio [aHR] 0.76 [95%CI = 0.69–0.84]) in phase 1, while in phase 2 they were more likely to do so (aHR = 1.44; 95%CI = 1.08–1.92). In both phases, people were more likely to switch if they had positive beliefs about its efficacy (phase 1: aHR = 1.76; 95%CI = 1.70–1.83; phase 2: aHR = 1.65; 95%CI = 1.54–1.77), and perceived getting vaccinated as the descriptive norm (phase 1: aHR = 1.30; 95%CI = 1.26–1.34; phase 2: aHR = 1.19; 95%CI = 1.13–1.25). During stricter lockdown measures people were also more likely to switch (phase 1: aHR = 1.26; 95%CI = 1.25–1.28; phase 2: aHR = 1.09; 95%CI = 1.08–1.09).

Conclusion A majority of initially hesitant people changed their minds about vaccination during the pandemic. Preference switches in favor of vaccination were most strongly associated with beliefs about the vaccine's efficacy in preventing illness. This study underlines the importance of providing up-to-date, balanced information and decisional support for people to weigh the benefits and risks of getting vaccinated versus not getting vaccinated.

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Highlights

- • A majority of initially hesitant participants switched toward vaccine acceptance.
- • Stronger efficacy beliefs and descriptive norms were associated with higher odds of switching.
- • Higher stringency of COVID policy measures was associated with more switches toward vaccination.
- • (Lower) concerns about side effects were not associated with switching.

Keywords Vaccination preference, Vaccine hesitancy, COVID-19 vaccination, COVID-19 pandemic, Cohort study

Introduction

Vaccination is a cornerstone of public health, having resulted in the near extinction of some infectious diseases while massively reducing the incidence of others. Vaccination programs are very effective in improving public health outcomes [1]. Their effectiveness on a collective scale, however, is dependent on a sufficient proportion of people being willing to get a vaccine. Unwillingness to vaccinate – in this context defined as a delay in acceptance or refusal of vaccinations – has been identified as a growing challenge for immunization programs [2]. The COVID-19 vaccination program has provided a unique learning opportunity to gain more insight into dynamics of the willingness to vaccinate and factors that influence change in people's vaccination preferences. The introduction of a new vaccine in a period of intensive data collection due to the acute pandemic crisis allows for studying in detail how people initially responded to the introduction of the vaccine, and which factors are related to switches in vaccination preferences. The current study set out to investigate which factors were associated with switches from initial unwillingness or hesitancy to later willingness to take the COVID-vaccines using longitudinal data from a large cohort study in the Netherlands.

While most studies on vaccination intentions have cross-sectional designs that preclude the study of change over time, some previous studies have investigated switches in vaccination intentions using longitudinal data. For example, one study on maternal hesitancy toward childhood vaccination suggested that increases in willingness to accept a vaccination were associated with increases in maternal confidence about the safety and efficacy of the vaccines [3]. Another study concluded that parents who were initially hesitant about an HPV vaccination for their children, were more likely to later accept the vaccine if they experienced greater social influence to vaccinate, had more knowledge about HPV, had a higher family income, were of white ethnicity, and reported lower perceptions of possible harms (vaccine safety) [4].

The COVID-19 vaccination campaign provided a unique context to study switches in vaccination intentions. For one, the pandemic crisis caused a very dynamic context (e.g., waves of infections) in which the vaccination decision was to be made. For instance, people received much information about the newly developed vaccines, but much was also still uncertain (e.g., longevity of the effectiveness). Another factor that may be more salient with the COVID-19 vaccination campaign compared to other vaccination programs was its link with societal participation. For instance, by introducing "COVID-19 certificates" the decision to get a COVID-19 vaccination influenced whether people had access to society. Also, as governments around the world were aiming at high proportions of vaccine acceptancy, decisions of the population as a whole affected the extent to which society could open in times of high virus circulation. Hence, factors at the individual, social and institutional level may have contributed to the dynamic context that affected (switches in) individual vaccination preferences.

Studies on switches in vaccination intention for COVID-19 vaccines are limited. One study in the United States considered demographic factors and switches in vaccination intention over a 2-month period and concluded that certain groups – particularly people who were middle aged, living in urban/suburban areas, Democrats, and of Asians ethnicity – were more likely to change vaccination preferences in favor of vaccination [5]. Another U.S. study reported that vaccination intentions were positively associated with perceived threat of the disease and decreased (particularly among Republicans) over a 5-month period, but this was before a vaccine became available [6]. Earlier research using two rounds of data (covering a period of 6 weeks) from the same cohort as the current study has shown that at the initial phase of the COVID-19 vaccination campaign in the Netherlands, vaccination intentions increased most when people received their personal invitation to get vaccinated. Next to that, beliefs about safety of the vaccines and about the vaccines being a way out of the crisis were associated with switches from initial unwillingness or hesitance to positive vaccination intentions [7]. In New-Zealand, it was shown that vaccination attitudes and efficacy beliefs were associated with positive changes in vaccination intentions over a 3-month period [8]. Interestingly, this initial work seems to suggest that efficacy beliefs play a larger role in switches toward vaccination than do risk perceptions (concerning the vaccine) – an implication that would align with research on fear appeals that consistently shows that risk perceptions

(severity and vulnerability beliefs) are weaker predictors of behavior change than efficacy beliefs [9].

The current study investigates the association of individual and contextual factors with switches from initial hesitance or unwillingness toward vaccination intention or uptake. It adds to previous work by considering a much longer period of time – 19 months - including 11 rounds of data collection. This allows not only for identification of switches in vaccination intention that occurred later in the campaign, but also for considering the impact of the pandemic on society as a contextual factor. At the individual level, we consider demographic factors, vaccination-specific beliefs, and perceived descriptive norms. While certain demographic variables have been associated with COVID-19 vaccination preferences (e.g., older people were more willing to vaccinate) [7], it is less theoretically obvious which of these would be associated with *switches* in vaccination intention. However, knowing that receiving one's actual invitation for vaccination was a factor that was associated with switches toward vaccine acceptance in the current population [7], it is plausible that younger people were less likely to make a switch in the initial phase of the COVID-19 vaccination campaign. This is because in The Netherlands older people were first invited. The vaccination-specific beliefs were based on the Reasoned Action approach [10]. The study included beliefs related to perceived benefits (efficacy: protection of self and others, vaccination as a way out of the crisis) as well as to perceived risks of vaccination (fear of side effects). Perceived descriptive norms were included as the behavior of close others is known to be associated with many preventive health behaviors including vaccination, e.g [11, 12]. In the current context, descriptive norms are of particular interest as they appeal to the interdependence between citizens that was inherent in the COVID-19 vaccination programs ('the higher our vaccination coverage, the sooner we will be out of this crisis'). At the contextual level, we investigated the role of time and societal restrictions, testing if switches in COVID-19 vaccine preferences could be understood from different phases in the pandemic, expressed in societal restrictions that were implemented to slow down the spread of the virus.

Altogether, the current study makes use of the unique opportunity to investigate the dynamics of vaccination intentions during the COVID-19 pandemic. Using 11 rounds of cohort data over a 19-month period between December 2020 and June 2022, the current study set out to answer the following research questions, (1) how many people who were initially unwilling or hesitant changed their mind about their first COVID-19 vaccination, (2) in which phase of the vaccination campaign were they most likely to do so, and (3) which factors were associated with a switch from initial unwillingness or hesitance about vaccination toward getting vaccinated?

Materials and methods

Study design and setting

We used data from a cohort study from the Dutch National Institute for Public Health and the Environment (RIVM), that ran from April 2020 to September 2022. Its aim was to monitor pandemic-related behavior and perceptions in the Dutch population during the COVID-19 pandemic. For the first round of data collection, respondents were recruited via existing panels and with the use of an 'open link' that was shared on social media (e.g., Instagram). To compensate for dropout over time, additional participants were recruited in rounds 3, 5, 6, 8, 10, 12, 13, 15, 17 and 19. The interval between rounds was every three weeks (rounds 1 to 4), every six weeks (5 to 19), and 13 weeks (20–21). The cohort is not representative of the broader Dutch population; for example, there are considerably more females than males (74% vs. 26%). A detailed cohort description can be found elsewhere [13].

Sampling procedures

We used data from individuals aged 18 years and over who participated from data collection round 9 (December 2020) onwards, because since then vaccine preference was systematically assessed. Round 10 (February 2021) was the first round of data collection since the Dutch vaccination campaign started (COVID-19 vaccines became available in the Netherlands in January 2021). For those who experienced the event (i.e., 'vaccinated' or 'intention to get vaccinated'), a total of 397,471 records that occurred after the event were removed (Fig. 1).

Because the analysis focuses on switching towards vaccine acceptance, we only included data from participants who initially indicated being unwilling or hesitant to receive a COVID-19 vaccination. Therefore, we removed data from 90,911 participants who reported the event at their first record (as they carried no information on any of the independent variables before vaccination), including 287 participants (0.3%) who initially intended to vaccinate but switched to being unwilling or hesitant to do so. After this, 6,483 participants were removed with only one record. This resulted in a study sample of 12,512 participants (with 44,106 records) which was used as input for the analysis addressing research questions 1 and 2 (i.e., alluvial plot and Kaplan-Meier, see Statistical Analysis).

For the analyses addressing research question 3 (i.e., cox regression analyses, see Statistical Analyses), we included only those participants who responded to both the vaccine beliefs items and the descriptive norm item. Therefore, those who enrolled after round 13 were

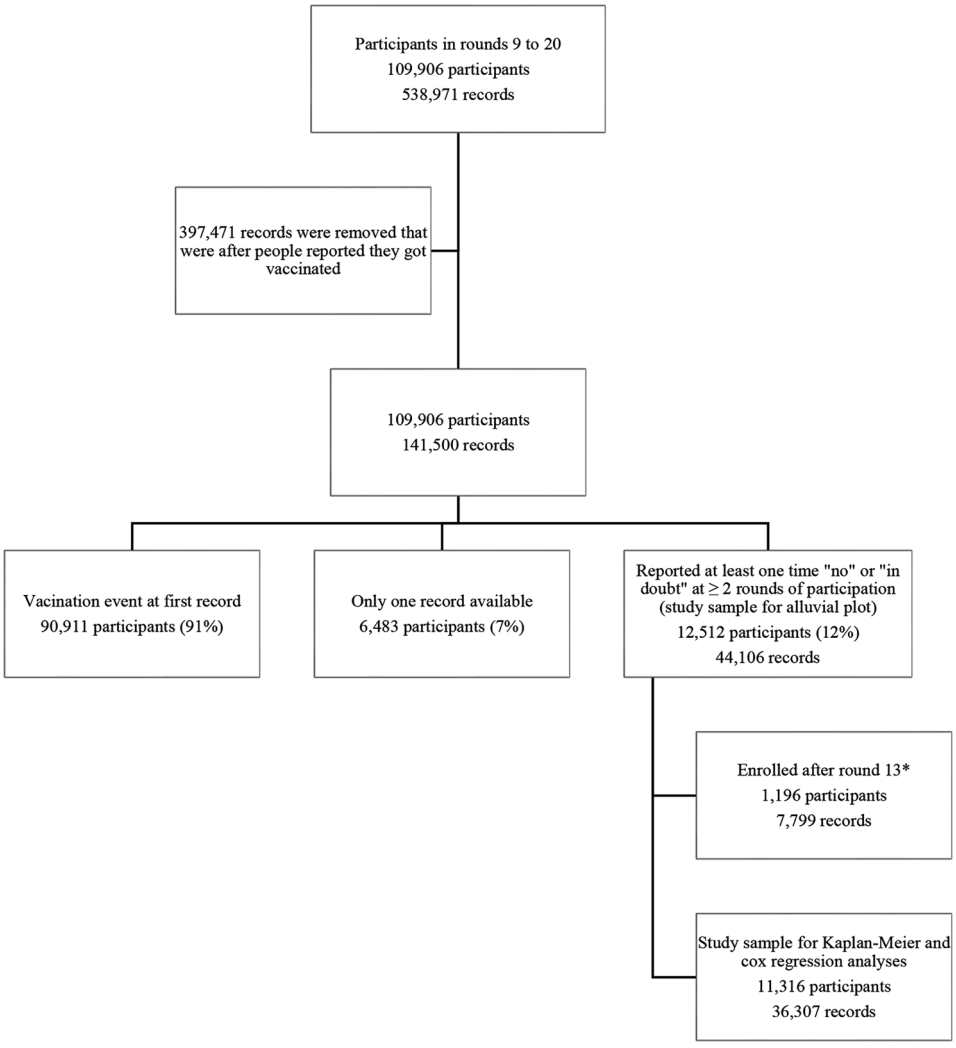

Fig. 1 Flow diagram. *Participants who enrolled after round 13 have no responses to the vaccine beliefs as used in the cox regression analyses

excluded (n=1,196). This yielded a sample of 11,316 participants with 36,307 records. Compared to those who were excluded from the cox regression analyses (n=1,183), those who were included were more likely to be female (p<0.001) and to live together (p=0.030).

Participant characteristics

Table 1 shows the sociodemographic characteristics of the participants included in the analyses. Most participants were female (74%), highly educated (53%), were living together (82%), and had no medical condition (77%).

Measures

Outcome variable

Preference regarding a first COVID-19 vaccination was asked using a single item: "Vaccination against the coronavirus is voluntary; it is your choice whether you want to be vaccinated or not. Have you had a vaccination against the coronavirus?". There were five response options: (1) "Yes", (2) "Not yet, but appointment has been made", (3) "Not yet, I want to make an appointment", (4) "No, I'm undecided about getting vaccinated", and (5) "No, I don't want to get vaccinated". The first three responses were categorized as 'yes or intention to' (i.e., the 'event'); the latter two - 'hesitant' and 'unwilling' - were used separately for the alluvial plots but were combined into 'unwilling or hesitant' for the regression analyses. To determine a change in preference – operationalized as a switch from 'unwilling or hesitant' to 'yes or intention to' – over time, we compared participants' responses at t(x) with their response at t(x+1). This allowed for determining associations between the independent variables and the outcome prospectively. Change in preference could take the value 1 (from negative to positive) or 0 (stable).

Independent variables

We assessed vaccination-specific beliefs about efficacy and vaccine safety (Supplementary Table S3), based on

Table 1 Characteristics of participants as included in the present study, Corona Behavioral Unit cohort, National Institute for Public Health and the Environment, the Netherlands, December 2020, through June 2022

Characteristic		Total		Active COVID-19 campaign phase (phase 1)					Residual COVID-19 campaign phase (phase 2)				
				Switched toward vaccination		No switch			Switched toward vaccination		No switch		
		n = 11,316		*n* = 6730		*n* = 877		*P*-value	*n* = 1606		*n* = 2103		*P*-value
		N	%	N	%	N	%		N	%	N	%	
Sex								0.061					0.081
	Male	2936	26.0	1716	25.5	198	22.6		419	26.1	603	28.7	
	Female	8380	74.0	5014	74.5	679	77.4		1187	73.9	1500	71.3	
Age								< 0.001					0.002
	70 + years old	883	7.8	692	10.3	29	3.3		55	3.4	107	5.1	
	55-69y	3024	26.7	2071	30.8	163	18.6		312	19.4	478	22.7	
	40-54y	4216	37.3	2432	36.1	301	34.3		649	40.4	834	39.7	
	18-39y	3193	28.2	1535	22.8	384	43.8		590	36.7	684	32.5	
Educational level								0.026					0.008
	Lower	1425	12.6	897	13.3	107	12.2		177	11.0	244	11.6	
	Middle	3896	34.4	2240	33.3	332	37.9		533	33.2	791	37.6	
	Higher	5995	53.0	3593	53.4	438	49.9		896	55.8	1068	50.8	
Living situation								< 0.001					0.173
	Living alone	2082	18.4	1248	18.5	168	19.2		270	16.8	396	18.8	
	Living together without children	3677	32.5	2427	36.1	236	26.9		458	28.5	556	26.4	
	Living together with children	5557	49.1	3055	45.4	473	53.9		878	54.7	1151	54.7	
Medical condition								0.004					0.658
	No	8848	78.2	5194	77.2	715	81.5		1278	79.6	1661	78.9	
	Yes	2468	21.8	1536	22.8	162	18.5		328	20.4	442	21.0	
Number of rounds participated		3 (3–5)		3 (3–4)		2 (2–3)		< 0.001	4 (3–6)		7 (4–10)		< 0.001
Vaccine protects		2.7 (2-3.3)		3 (2.7–3.5)		2.3 (1.7-3)		< 0.001	2.8 (2.2–3.3)		2 (1.4–2.6)		< 0.001
Vaccine has little side effects		2 (1-2.5)		2 (1.5-3)		2 (1–2)		< 0.001	2 (1.1–2.5)		1.6 (1-2.1)		< 0.001
Descriptive norm		3.4 (2.5-4)		4 (3-4.2)		3 (2–4)		< 0.001	3.7 (3–4)		3 (2–4)		< 0.001

Note that totals might not add up due to missing values

Medical condition: physical condition that increases the likelihood of severe COVID-19 when infected

"Vaccine protects:" perception that COVID-19 vaccine offers protection

"Vaccine has little side effects:" perception that COVID-19 vaccine has little side effects

Descriptive norm: perception that others have been or planning to get vaccinated against the corona virus

Active phase: period that covers data collection rounds 9 to 13, when the first Dutch vaccination campaign was still running and people became eligible for their first COVID-19 vaccination based on their age, starting with the oldest people

Residual phase: period that covers data collection rounds 14 to 20, during which all people 18 years and older were eligible for a first COVID-19 vaccination for some time and were still able to get vaccinated

Continuous variables presented as median (IQR) and compared using the Kruskal-Wallis test; categorical and binary variables presented as n (%) and compared using Pearson χ 2 tests

the Reasoned Action Approach [10]. Participants were asked to rate six items such as, "If I get the vaccine, I will be protected against the coronavirus", using 5-point Likert scales ranging from [1] totally disagree to [5] totally agree. To assess the construct validity of the set of beliefs, a factor analysis with oblimin rotation was performed, and Cronbach's alpha and Corrected Item-Total Correlation statistics were calculated to assess internal consistency. We identified two clusters: (1) efficacy beliefs (4 items), related to the vaccine's protective effects in terms of one's own and others' health as well as in fighting the pandemic, and (2) concerns about side effects of the vaccine (2 items) (Supplementary Table S1). Individual mean scores were calculated for both clusters. Because the vaccination-specific beliefs were asked in rounds 10 to 13 and thus were missing by design in later rounds, we extrapolated each participant's mean score up to round 13 to any future rounds.

Descriptive norm was assessed with a single item: "Most of my friends and family have been or are planning to get vaccinated against corona", (c.f [10]). on a 5-point Likert scale ranging from [1] totally disagree to [5] totally agree, and with an option of [6] 'don't know'. This latter option was recoded into missing. We calculated each participant's mean up to round 17 and extrapolated this to future records where this variable was missing by design.

To determine whether switches in vaccination intentions were associated with societal restrictions that were implemented to mitigate the spread of the virus, we used the mean score of the COVID-19 Stringency Index between two rounds [14]. The index includes information on nine restrictions on daily activities such as school closings or restrictions of group size, and one indicator of a public health campaign being active (Supplementary Table S2). The index ranges from 0 (no measures) to 100 (strictest measures).

We used the following baseline demographic variables: age at time of enrolment (pre-defined categories: 70+years, 55–69, 40–54, 18–39)[1], sex (male, female), educational level (lower: elementary school, vocational, and technical education; middle: secondary education in preparation to higher education, and vocational education higher level; and higher: higher professional education and university education), living situation (living alone, sharing household without kids, and sharing household with kids), and having an underlying medical condition, such as heart disease, that increases the likelihood of severe COVID-19 when infected (yes, no).

[1] The reason for using 70+as a cutoff for our oldest age group is that citizens aged 70 or older were considered a "high-risk group" in the Dutch vaccination campaign and were among the first to receive their invitation for a COVID vaccine. After allowing high risk groups first, invitations to vaccinate were sent out to all citizens based year of birth, starting with the oldest.

Ethical statement

The Centre for Clinical Expertise at the National Institute for Public Health and the Environment declared that the study (Study number G&M-561) was not subject to medical ethical review according to the criteria laid down in the Dutch Law for Research Involving Human Subjects (WMO). Participants were informed in writing about the study, their voluntary participation and the type of data collected, after which they were asked for their informed consent. After completing the first questionnaire, participants were asked for consent to receive follow-up invitations. Participants were informed that they could withdraw from the study at any time. Data collection was outsourced to a research agency ('Research 2Evolve').

Statistical analyses

Alluvial plots were used to depict switches in vaccine preference over time. Kaplan–Meier method was used to estimate the overall cumulative incidence of the event (vaccinated or intending to do so) over time. Univariable and multivariable extended cox regression models were used to calculate (adjusted) hazard ratios ((a) HRs; 95%CI) representing the relative risk of the event of interest. Cox regression was chosen because it allows for the analysis of time-to-event data such as our cohort data while adjusting for covariates, making it well-suited for examining the timing and predictors of changes in vaccination intentions over the study period. For participants who did not report the event, the last observation was assumed to be their outcome, a method known as 'censoring'. This approach acknowledges that their actual probability of getting vaccinated after that point is unknown.

Models included age, sex, educational level, perceived descriptive norms of COVID-19 vaccination, vaccination-specific beliefs (i.e., efficacy and concern about side effects), and stringency index of the imposed COVID-19 preventive measures. We included time-varying covariates (vaccination-specific beliefs, descriptive norm, and stringency index) into the models, and assumed that the relation between fixed effect baseline covariates and the outcome changed over time (i.e., the hazards were unlikely to be proportional). For example, age may have different effects in the active phase of the campaign – when participants became eligible based on their age – versus the residual phase. Additionally, as more time passed since the vaccine introduction, there was increasing evidence that severe side effects were very rare, potentially enhancing the perceptions of safety and effectiveness later time points. Therefore, we stratified the cox regression analyses into two periods: (1) the active phase of the vaccination campaign (data collection rounds 10 to 13; when people became over time eligible for their first COVID-19 vaccination based on their age, starting

with the oldest people), versus (2) the residual phase of the campaign, during which all people 18 years and older were eligible for a first COVID-19 vaccination for at least two weeks before we sent out a new questionnaire (rounds 14 to 20).

To measure similarities between observations within the same participants, intraclass correlation coefficients (ICC) were calculated for the time-varying variables. Higher ICC would indicate that the observations within the same group were more similar. The following cut-off points were used; "low" (below 0.50), "moderate" (0.50–0.75), and "high" (above 0.75) [15].

A $p<0.05$ was considered statistically significant. Alluvial plots were generated using the 'ggalluvial' package in *R* [16], Kaplan-Meier and cox regression analyses were performed with the 'sts graph' and 'stcox' commands in *Stata*, respectively [17].

Results

To answer research question 1, switches in vaccination preference were visualized with an alluvial plot (Fig. 2). The streams indicate that during the first five rounds (rounds 9–13), a notable number of participants who were initially 'hesitant', switched toward vaccination (getting the vaccine or intention to do so; 'intention/yes'). In later rounds, the number of participants who were hesitant stabilized (below 20%). Switches towards vaccination among those who did not want to get vaccinated ('unwilling') was less evident, even in the earlier rounds, and although their number remained relative stable during the study period, the proportion of unwilling participant increased as more and more participants got vaccinated. Note that these data are descriptive and do not reflect significance.

Overall, out of the 8,658 participants who were initially hesitant, 7,411 (86%) switched toward vaccination eventually. In contrast, of the 3,854 participants who were initially unwilling, 1,324 (34%) switched toward vaccination, while 2,316 (60%) remained unwilling in their last survey.

To answer research question 2, a Kaplan-Meier method was used to estimate the overall cumulative incidence of the event (vaccinated or intending to do so) over time. The Kaplan-Meier estimator of the survival curve for time to switching towards vaccination yields an impression of when participants made this switch (Fig. 3). By the end of phase 1, the cumulated proportion of participants who switched was 61.9% (95%CI=61.0–62.8), while at the end of phase 2, this was 80.5% (95%CI=79.7–81.3). The median time at which participants switched to vaccination was the 12th round (March 2021); the median time to accomplish this was 2 rounds.

To answer research question 3, time-dependent cox regression models were fitted to the outcome variable in relation to vaccination-specific beliefs, descriptive norm and stringency level of policy measures while correcting for socio-demographic variables. Model 1 is a univariate model including age. Model 2 extended Model 1 by including sex, and other socio-demographic variables such as educational level and household size. Model 3 extended model 2 by including vaccination-specific beliefs and norms. Model 4 also included the policy stringency level. Below we present the results from Model 4 for both the active COVID-19 vaccination campaign phase (phase 1) and the residual COVID-19 vaccination

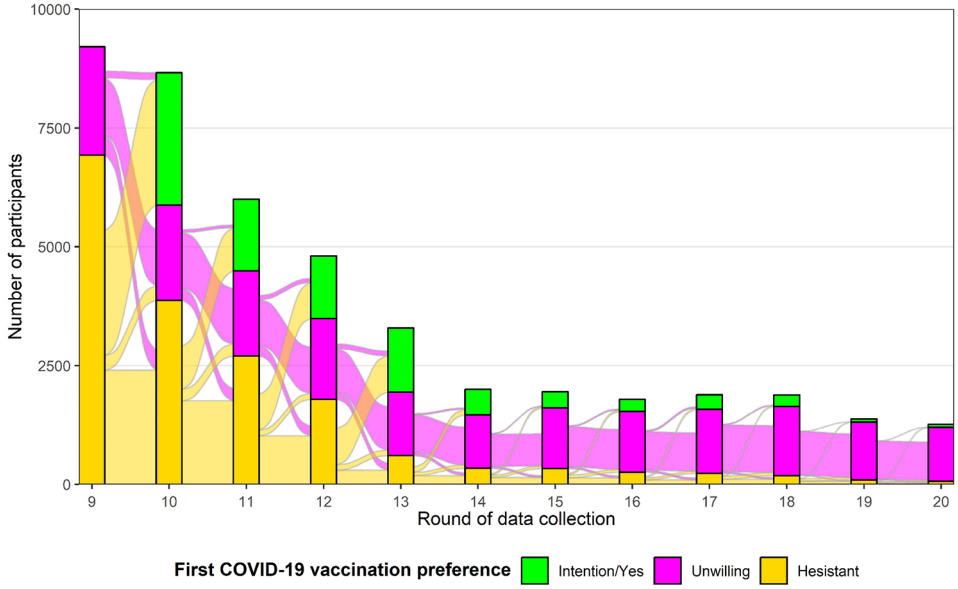

Fig. 2 Transitions in vaccination preference over time between round 9 and round 20 among 12,512 participants (accounting for 44,106 records) of the Corona Behavioral Unit cohort, National Institute for Public Health and the Environment, the Netherlands, December 2020 through June 2022

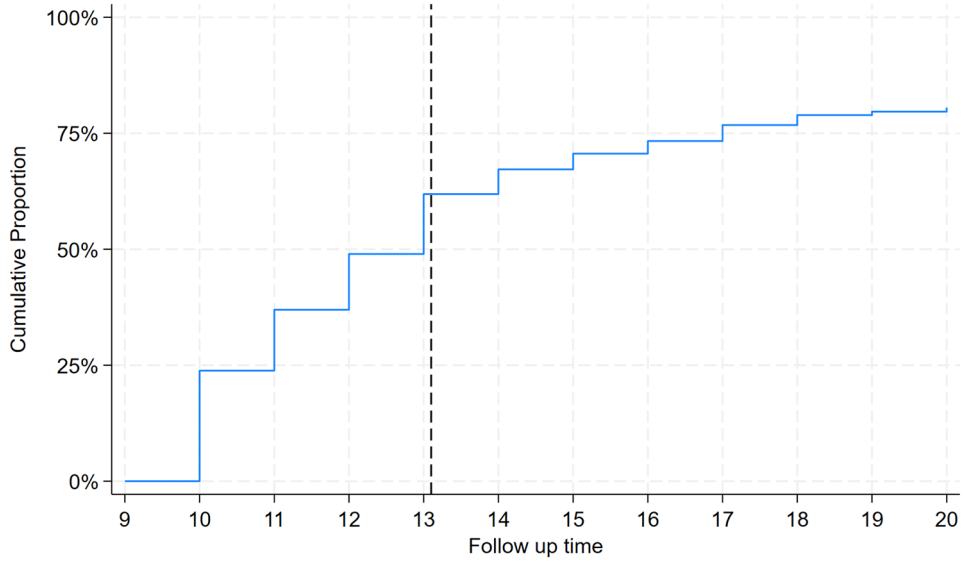

Fig. 3 Kaplan Meier estimates of time from first participation after round 9 to making a switch in preference of getting a first COVID-19 vaccination or having the intention to do so among those participants who were initially unwilling or hesitant about getting one, Corona Behavioral Unit cohort, National Institute for Public Health and the Environment, the Netherlands, December 2020 through June 2022. Note. The dashed line denotes the end of the active COVID-19 vaccination campaign

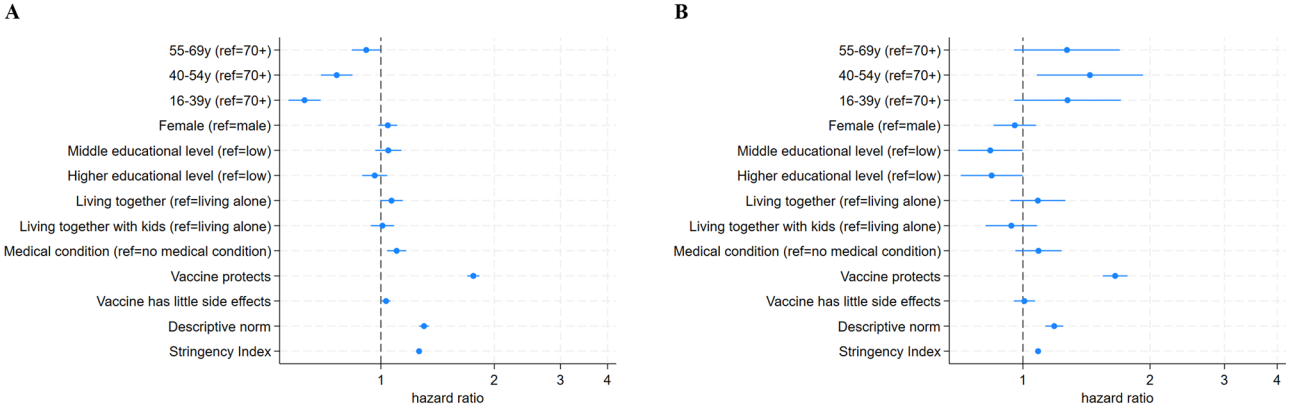

Fig. 4 Adjusted hazard ratios of time to get a first COVID-19 vaccination, controlled for age, sex, educational level, living situation, medical condition, vaccine beliefs and descriptive norm, among 11,316 participants of the Corona Behavioral Unit cohort, National Institute for Public Health and the Environment, the Netherlands (RIVM), December 2020 through June 2021 (phase 1; 4 A), and July 2021 through June 2022 (phase 2; 4B)

campaign phase (phase 2). Results from the univariable model and the other multivariable models yielded similar results for both phases (Supplementary Table S3a and S3b).

The final cox regression (model 4) revealed that, compared to participants aged 70 and over, participants aged 40-54y had a 24% lower chance of switching toward getting vaccinated during the active COVID-19 campaign phase (adjusted hazard ratio [aHR] 0.76 [95% CI=0.69–0.84]), while for 16–39 year olds this was 37% (aHR=0.63; 95% CI=0.57–0.69; Fig. 4a). In addition, compared to participants living alone, those living together without kids had a 7% higher chance of switching toward getting vaccinated (aHR=1.07; 95%CI=1.00-1.14). Those with a medical condition had a 10% higher chance compared to participants without a medical condition (aHR=1.10; 95CI%=1.04–1.17). Stronger vaccine efficacy beliefs were associated with a higher chance to switch, with each step on the 5-point scale corresponding to a 76% higher chance of getting vaccinated (aHR=1.76; 95%CI=1.70–1.83), while concerns about side effects were only slightly associated with the chance of switching (3%; aHR=1.03; 95%CI=1.00-1.06). Furthermore, a more positive descriptive norm was associated with a 30% greater chance of switching (aHR=1.30; 95%CI=1.26–1.34). During periods of more stringent lockdown measures, participants had a 26% higher change to switch toward getting vaccinated (aHR=1.26; 95%CI=1.25–1.28). There was no evidence of any differences in switching to vaccination for sex and level of education.

The final cox regression (model 4) for the residual COVID-19 vaccination campaign phase showed that, compared to the reference group (participants aged 70 years and over), 40 to 54 years olds had a 44% higher chance of switching toward getting vaccinated (aHR = 1.44; 95%CI = 1.08–1.92; Model 4 in Fig. 4b). There was no evidence of any differences between 70 + year olds and younger participants. Also, compared to lower educated participants, those who had a middle to higher educational level had a 16% lower chance of switching toward getting vaccinated, (aHR = 0.84; 95%CI = 0.70-1.00 and aHR = 0.84; 95%CI = 0.71-1.00, respectively). Stronger vaccine efficacy beliefs were associated with a greater chance of switching, with each step on the 5-point scale corresponding to a 65% higher likelihood of getting vaccinated (aHR = 1.65; 95%CI = 1.54–1.77). Also, a more positive descriptive norm was associated with a higher chance of switching, 19% for each step on the 5-point scale (aHR = 1.19; 95%CI = 1.13–1.25). During stricter lockdown measures, participants had a 9% higher change to switch toward getting vaccinated (aHR = 1.09; 95%CI = 1.08–1.09). There was no evidence of differences in switching toward getting vaccinated for sex, living situation, medical condition and for the degree in which people were concerned about side effects of the vaccine.

To evaluate whether participants tended to have similar responses over time, the intraclass correlation coefficient (ICC) was used. For vaccine efficacy beliefs, concerns about side effects, and perceived descriptive norm, the ICC were 0.77, 0.60 and 0.71, respectively. These indicate that for all time-varying variables most variability was observed between-subjects, but we also see some variability within individuals over time.

Discussion

The current study set out to investigate which demographic factors, vaccination-specific beliefs, and contextual factors were associated with switching from initial hesitance or unwillingness to vaccinate toward getting a vaccine or having the intention to do so. Longitudinal analyses on 11 rounds of data collection in a cohort study stretching over a period of 19 months revealed that the majority of participants who indicated initial reluctance (being unwilling or hesitant about vaccination) changed their mind, especially those who were hesitant (vs. those who were initially unwilling to get a vaccination). Switching toward getting vaccinated was less likely to occur when more time had passed.

The regression analyses revealed that switching was most strongly associated with age and with beliefs about the benefits of vaccination (i.e., efficacy beliefs). During the active phase of the vaccination campaign, in which people were invited on the basis of their age starting with older people, older participants were more likely to switch toward getting vaccinated, while in the residual phase the opposite was the case. A plausible explanation would be that older age groups became eligible for vaccination earlier than younger age groups and thus had more time to (re-)consider their decision during the active phase of the campaign. The relatively small number of older people (age 70+) who were still not vaccinated during the residual phase of the campaign, while having been eligible longer than younger age groups, were likely to be quite certain of their decision. Similarly, our finding that people with a lower education level (vs. those with higher education levels) were somewhat more likely to switch during the residual phase of the vaccination campaign, seems to indicate that higher educated people sooner reached their final decision. Vaccination uptake is generally higher among higher educated people [18], but those who are unwilling to vaccinate may be so for reasons that are less likely to change over time (e.g., religious beliefs). Beliefs about the efficacy of vaccination were strong positive predictors in both follow-up periods. Interestingly, their association with switches toward vaccination intention was much stronger than that of concerns about potential side effects of vaccination. This is in line with prior research on risk communication which has also shown that efficacy beliefs are generally more important predictors of behavior than risk perceptions, e.g [9]. This is not to say that safety concerns do not play a role in vaccination decisions: concerns about side effects are often mentioned by participants who decline a vaccination, (e.g [19]). , and are often reported as the main reason to not get the vaccine [20]. Hence, transparent communication about known risks of vaccination is important. Next to that, our current study suggests that, as vaccination campaigns progress and the effectiveness of vaccination is observable in practice, effort should be put into communicating about this effectiveness and the negative outcomes (in terms of illness cases and pressure on the health care system) that were prevented because of the vaccination program.

Apart from the demographics and vaccination beliefs, perceived positive descriptive norms (i.e., 'close others are also vaccinated') and higher societal restrictions also appeared to trigger a change in vaccination preference. Associations between descriptive norms and vaccination intentions are commonly found (e.g [11]). , and interventions showing an effect of presenting descriptive norm information on vaccination intentions suggest a causal relationship [21]. For people who were initially hesitant or unwilling to get vaccinated, a social environment in which many close others are vaccinated may have functioned as a decisional short-cut (i.e., conformity bias), it may have relieved some initial concerns about vaccination, or even yielded pressure to change their mind. To what extent close others played an active role in

preference switches (e.g., by putting pressure on people or by supporting their decision process in a more constructive way) is a question that remains open for future research.

The observed association with stricter pandemic mitigation measures may be explained by the fact that a greater strictness of measures corresponded to a more severe episode in the pandemic which may have caused a higher perceived risk of infection. It could also imply that during times of strict measures, participants were motivated to get vaccinated so that they had (more) access to public spaces such as restaurants (e.g., by means of providing a 'COVID-19 certificate'), or that our participants were aware that getting a vaccination might affect the extent to which society could open in times of high virus circulation as a collective gain. Both of these reasons – to gain more access to society and to help end the crisis and reopen society – were indeed explicitly mentioned by participants in our cohort study as motives to get their vaccination [7].

It is important to note that our analysis did not aim to test whether a change in vaccination-specific beliefs preceded a change in vaccination preference. In fact, Intra-Class Correlations for the vaccination-specific beliefs showed that they were relatively stable over time, in particular the perceptions of vaccine efficacy which were the strongest predictor of switching preferences. The suggestion that relatively stable beliefs can still be associated with a change in preference over time underscores the importance of providing reliable and transparent information about the vaccines from the start of a vaccination program. At the same time, the considerable within-subject variability indicates that beliefs may have been adjusted to some extent during this (novel) vaccination program, advocating for repeated and updated information about vaccine safety and effectiveness throughout a campaign.

Altogether, our study is one of the few to provide a longitudinal perspective on the dynamics of preference change for receiving a vaccination. This adds to work studying vaccination preferences at single timepoints. The current findings show which factors make people more or less likely to change their initial vaccination preference. Importantly, the relative weight of these factors may differ between individuals and within individuals over time. Our finding that the stringency index for COVID-19 measures played a role in preference switches suggests that dynamics of the societal context – in terms of (perceived) severity of the threat and concurrent impact of public policy measures – are relevant to consider when studying vaccination preferences in the context of a pandemic. Such factors seem less explicitly represented in some of the theoretical models that are used to predict vaccination uptake such as the Reasoned Action Approach [10] or Protection Motivation Theory [22]. However, although we have no reason to a priori believe that results would be different in other samples, for other vaccines, or in future pandemics, we do not feel confident to make strong claims about the generalizability of the current findings given the limited number of studies addressing switches in vaccination intention over time.

Finally, our finding that the belief in the efficacy of the vaccine and the societal restrictions at the moment of decision were important factors implies that offering clear and trustworthy information about the effectiveness of vaccination both in terms of individual protection as well as in terms of alleviating societal stress could be helpful for people who value this information to make their vaccination decision. Although beyond the scope of the current study, we would like to add that next to risk perceptions and (response) efficacy beliefs, self-efficacy (the belief that one is capable of actually getting the vaccine) and perceived barriers are also typically found to be important predictors of vaccine uptake (e.g [23]). , . Hence, facilitating uptake for those who want to get vaccinated should be a major point of attention of vaccination programs [24].

Limitations

This study is based on repeated measurements within respondents who participated at least twice in the Corona Behavioral Unit cohort that was established by the Dutch National Institute of Public Health and the Environment. While offering a unique and rich dataset, demographics of the sample are not representative for the Dutch population. We tried to address this by controlling for demographic factors in our analyses. Also, the average vaccination rate in the sample was higher than in the Dutch population (96% in the last round we included versus 82% nationally). This means that we may have missed factors that are relevant for underrepresented groups, or that we overestimated the effects of factors that are only relevant for the overrepresented groups. Second, we recognize some limitations in the operationalisations of included constructs: the descriptive norm was assessed with a single-item measure, precluding error estimations. A limitation of the stringency index used as a proxy for societal impact is that it may affect participants differently. For example, school closings or the requirement to work from home may affect people differently depending on their personal circumstances, and thus their decisions regarding vaccination. A final limitation was that we were unable to include other potentially relevant determinants. Particularly, illness risk perceptions and trust in the government would be factors that are typically found to be related to vaccination intentions and can be quite variable over time (although their association with

preference switches has not been studied). Seeing how longitudinal studies that can provide insight into the dynamics of vaccination intentions provide an important addition to cross-sectional work on understanding vaccine hesitancy, we encourage other researchers who have longitudinal data available or are designing longitudinal studies in the future to see whether these additional factors could be considered.

Future work could also include a more in-depth investigation of switches in vaccination preferences. Our study highlights associations with preference switches but cannot determine what were crucial causal factors for people's change of mind. More research is needed to study what people themselves identify as key factors (e.g., certain information, contact with others, societal circumstances) that made them change their minds about vaccination and consider if that has implications for supporting people in getting what they need to make a decision (be it in favor of or against vaccination). In addition, future research could gain more insight into 'reverse switches' (i.e., from an initial intention to get vaccinated to later hesitance or refusal). Although these were rare in our study (<1% of cases) where we only considered the first dose of the COVID-19 vaccination, this may be more likely to occur when considering multiple vaccine doses over time. Vaccination uptake rates show that people who accepted a first COVID-19 vaccine not all accepted a booster vaccine as well (see [25] for a report on vaccination coverage in the Netherlands). Shedding light on (bidirectional) switches in vaccination preferences over multiple doses of a vaccine could help explain such findings.

Conclusions

This study showed that a majority of initially hesitant people switched toward a positive vaccination intention during the COVID-19 vaccination campaign. Switching was most strongly associated with beliefs regarding the efficacy of the vaccine, increasing stringency of measures, and the perceived vaccination choices of close others (descriptive norm). Finding that, for a novel vaccine, vaccination preferences are not static and switches in vaccination preferences are associated with individual, social, and contextual factors, has implications for research and practice. We encourage future research to invest in additional longitudinal studies on vaccination preferences to learn more about the generalizability of the current findings and about 'reverse switches'. For practice, the current findings suggest that continued, up-to-date information about vaccine effectiveness – in terms of personal health effects as well as effects on society - may help people who were undecided to make a decision.

Supplementary Information

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Supplementary Material 1

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Author contributions

All authors attest they meet the ICMJE criteria for authorship. FK, ML, MdB initiated and designed the study. FK, ML, VB, PvE, MH, RR, DT conceptualized the current research questions and analysis plan. WvdB analyzed the data and generated the visualizations. All authors were involved in interpreting the results. FK, ML and WvdB wrote the first draft. All authors critically reviewed and approved the submitted manuscript.

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Data availability

Due to the General Data Protection Regulation (GDPR), a European Union (EU) privacy regulation (in the Netherlands referred to as the AVG, or 'Algemene Verordening Gegevensbescherming'), data cannot be shared publicly, unless aggregated. For academic collaborations and publishing in scientific journals, we have initiated a Behavioral Science Consortium ('Be-Prepared') with researchers working at universities as well as the RIVM. In this way we can collaboratively work on further analyses of the data and publish more in-depth papers on several topics.

Declarations

Ethics approval and consent to participate

The cohort study did not meet the requirements for ethical review as laid down in the Dutch Law for Research Involving Human Subjects (WMO) and was therefore exempted by the Centre for Clinical Expertise at RIVM from formal ethical review (Study number G&M-561). Written informed consent was provided by all participants. After completing their first questionnaire, participants were asked for consent to receive follow-up invitations. Participants were informed that they could withdraw from the study at any time.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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