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Vaccination or restriction?: COVID-19 vaccine hesitancy and vaccine passports

Short title: COVID-19 vaccine hesitancy and vaccine passports

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Abstract

Objectives: While the development of vaccines against the novel coronavirus (COVID-19) brought the hope of establishing herd immunity, which might help end the global pandemic, vaccine hesitancy can hinder the progress towards herd immunity. In this study, we assess the determinants of vaccine hesitancy, reasons for hesitation, and effectiveness of vaccine passports in relaxing public health restrictions.

Methods: Through an online survey that includes a conjoint experiment of a demographically representative sample of 5,000 Japanese adults aged 20–74, we assess the determinants of vaccine hesitancy, reasons for hesitation, and effectiveness of hypothetical vaccine passports.

Results: We found that about 30% of respondents did not intend to vaccinate or have not yet decided, with major reasons for vaccine hesitancy being related to concerns about the safety and side effects of the vaccine. In line with previous findings, younger age, lower socioeconomic status, and psychological factors such as weaker COVID-19 fear were associated with vaccine hesitancy. The easing of public health restrictions such as travel, wearing face masks, and dining out at night was associated with an increase in vaccine acceptance by 4–10%.

Conclusion: Vaccine hesitancy can be reduced by mitigating the concerns about vaccine safety and side effects, as well as by relaxing public health restrictions. However, the feasibility of vaccine passports needs to be sufficiently assessed, taking the ethical issues of passports and the public health impacts of the relaxation of restrictions into careful consideration.

Strengths and limitations of this study

- This study includes timely data on COVID-19 vaccine hesitancy, obtained from a demographically representative sample of 5,000 Japanese adults.
- A conjoint experiment allows assessing the effectiveness of easing public health restrictions on vaccine acceptance.
- Actual behaviour may diverge from the survey responses or fluctuate due to the pandemic situation and the timing of the survey.
- Results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy can vary across countries.

Introduction

After a period when nations have managed to curb the spread of the new coronavirus disease (COVID-19), mainly by non-pharmaceutical interventions such as containment and closure policies, the development of COVID-19 vaccines brought hope that the pandemic may end soon. Although the degree and duration of vaccine efficacy as well as the efficacy against new virus variants remain unconfirmed, widespread vaccination can contribute to establishing herd immunity against COVID-19. While the required proportions of individuals with immunity could vary by country (e.g. due to demographic structure and frequency of human contact), it is estimated that approximately 70% of the population needs immunity to achieve herd immunity against COVID-19, which would require more than 30 million deaths worldwide due to natural infection [1]. Therefore, global vaccination is a necessary step to end the pandemic.

However, the vaccine hesitancy, defined as a 'delay in acceptance or refusal of vaccines despite availability of vaccine services' by a working group advising the World Health Organization [2], can hinder achieving herd immunity. The findings of systematic reviews and meta-analyses suggest that the vaccine acceptance rates are around 60–75% but show large discrepancies across regions, months of study, and whether an answer of 'unsure' is available to survey respondents [3, 4]. Together with the global disparities in vaccine availability for COVID-19, full vaccination rates are considerably low, and only about a third of the world population had received at least one dose of a vaccine against COVID-19 by August 2021 [5]. While this low vaccine uptake may be due to many reasons, including factors other than individual preferences, such as system failures, it is important to identify why people are reluctant to vaccinate to establish herd immunity by avoiding preventable vaccine hesitancy.

Whether an individual accepts vaccination is a consequence of a complex decision-making process, which occurs on the continuum between complete acceptance and refusal [2]. The above-mentioned working group developed the 'three Cs vaccine hesitancy model', which comprises confidence, complacency, and convenience, indicating that historic, socio-cultural, environmental, health system/institutional, economic or political factors, as well as personal perception and vaccine/vaccination characteristics matter towards vaccine hesitancy. Moreover, from a utilitarian perspective, voluntary vaccinations can deviate from the social optimum due to the positive externalities of vaccinated individuals; hence, Pigouvian subsidies, external regulations, or strategies to improve vaccine awareness is needed, depending on the nature of vaccine-preventable diseases and vaccines [6, 7].

Therefore, it is important to understand the reasons of those who tend not to accept a COVID-19 vaccine, in addition to strategies to raise the vaccination rates. In the following section, we review the literature on the determinants of COVID-19 vaccine hesitancy.

Literature on COVID-19 vaccine hesitancy

(1) Socio-demographic factors

Given the concerns of the increasing hesitancy towards COVID-19 vaccination, many empirical studies have hitherto assessed factors associated with COVID-19 vaccine hesitancy [3, 8-11]. These studies suggest that many empirical papers find that older people compared to their younger counterparts and men compared to women are more likely to accept a COVID-19 vaccine. Older people are susceptible to the disease and while men and women can decline vaccination for different reasons, the differences in perceived risks, efficacies, and knowledge may mediate these gender

differences [11]. In addition to age and gender, educational attainment is identified as the most frequent predictor, with higher acceptance among people with higher education levels [3]. While highly educated individuals can be vaccine-hesitant because of the influence of social groups and other authorities, education may play an important role in understanding disease severity and vaccination benefits [11].

(2) Psychological and behavioural factors

Vaccination is a consequence of one's utility maximisation, considering costs and benefits. Based on the health belief model, by modifying socio-demographic factors, individuals can decide whether to vaccinate as a reflection of their personal beliefs about a disease and its preventive measures, such as susceptibility, severity, benefits, barriers, and self-efficacy [12, 13]. A systematic review identifies that vaccine acceptance is higher among those with greater perceived risk, threat, vulnerability, and susceptibility to infection [8, 9]. Furthermore, the beliefs about the vaccine are predictors of vaccine hesitancy, including mistrust in its safety or efficacy and conspiracy beliefs, which can be induced by a low health literacy and negative information in the media [8].

Together with one's perceptions regarding vaccines and infection, individual preferences matter for health-related decision-making, including vaccination [14, 15]. Time preference affects one's vaccination intentions because individuals will benefit from the vaccination in the future, despite having to bear its present costs. Therefore, those discounted future benefits would lead them to decide not to vaccinate. Moreover, the attitudes toward risks are attributed to vaccination decision-making, that is, risk-averse individuals would feel conflicted between the risk of infection without vaccination and the vaccines' side effects. This would explain why younger people

tend to be vaccine-hesitant, considering they are less likely to develop symptoms than their older counterparts [16] and have more frequent side effects [17]. In addition to individuals' attributes and beliefs, vaccine characteristics are important determinants of vaccination intention, being highly relevant to individuals' perceptions and preference for vaccines. In particular, individuals prefer vaccines with higher efficacy, longer duration of disease protection, and safety (i.e. none or few adverse effects) [8, 18].

Vaccination campaigns

To increase vaccination rates, considering the determinants of vaccine hesitancy discussed above and vaccine characteristics, potential strategies would include removing the (mis)perceived effectiveness and risks of vaccination and infection, minimising the costs associated with vaccination (i.e. out-of-pocket payments and opportunity cost), and increasing the benefits of vaccination by providing various incentives. In fact, several approaches, such as communication, financial and non-financial incentives, and reminder-recall interventions, have been adopted and evaluated so far [19, 20].

Vaccination campaign frameworks have also been adopted to increase the COVID-19 vaccination uptake. Aiming at a better understanding of the population for COVID-19 vaccines, public organisations disseminate information about the efficacy and safety of vaccines [21, 22]. Additionally, a study suggests that emphasising the benefits of vaccination and inducing feelings of vaccine ownership are useful [23, 24], thus suggesting the importance of information campaigns. In some countries, the convenience of vaccination locations is enhanced by providing these services within the areas of citizens' daily lives, such as train stations and supermarkets [25, 26].

Furthermore, the incentives toward vaccination attract the attention of some policymakers [27] although their effectiveness remains inconclusive and may depend on how incentives are given [28, 29].

With remaining ethical concerns, vaccine passports, which fully or partially exempt vaccinated individuals from public health restrictions [30, 31], are considered in many regions. While only a limited number of related studies are available, the freedom allowed by vaccine passports can affect vaccine acceptance and preference [29, 32]. Despite the concern about `breakthrough infections', it would be worth considering the applicability of vaccine passports if and only if the passports largely contribute to achieving herd immunity against COVID-19 by increasing vaccine acceptance.

Contributions of this study

Previous studies have documented the determinants of vaccine hesitancy by analysing the association of socio-demographic, psychological, and vaccine characteristics with vaccine intentions. Meanwhile, the evidence on how to increase COVID-19 vaccine acceptance remains scarce. In alignment with the policies in several regions, the evidence on communication strategies and the incentives for reducing vaccine hesitancy have gained increasing attention, as discussed above, while the effectiveness of vaccine passports in raising vaccine acceptance has been limited. While countries such as Israel, France, and Italy attempt to utilise vaccine passports, other countries may also consider similar schemes to return to a 'normal life'. If so, it is immensely important to accelerate herd immunity by reducing avoidable vaccine hesitancy, to which the benefits of the vaccine passports may contribute.

Therefore, we assess the effectiveness of easing public health restrictions

after vaccination by vaccine passports based on our analysis of a conjoint experiment. By decomposing the freedom factors allowed by the passport based on government regulations, we first evaluate an effective type of relaxation of public health restrictions to increase vaccine acceptance, which would be useful for health policymakers to design vaccine passports and deliver attractive information on the benefits of vaccination for vaccine-hesitant individuals.

Methods

Data

The data come from a demographically representative sample of 5,000 Japanese adults aged 20–74, which was conducted online during 21–23 July 2021. Survey respondents were recruited from registered panels of Cross Marketing Inc. To ensure that the survey is nationally representative regarding respondents' age and gender, we recruited respondents using quota sampling for each of the 14 age groups of the 2015 population census (i.e. age categories of 20s, 30s, 40s, 50s, 60s, and early 70s by gender).

While we did not use regional quotas to recruit respondents, we addressed the potential non-representativeness arising from this by using weights for all analyses and estimated by population structures in each region. Specifically, we used eight categories for residential areas (i.e. Hokkaido, Tohoku, and Kanto, except for the Tokyo Metropolitan Area, Tokyo Metropolitan Area, Chubu, Kinki, Chugoku, Shikoku, and Kyusyu) and eleven categories for each five-year age group from 20 to 74.

Ethical approval

This study was approved by the Institutional Review Board of the Institute of

Economics Studies, Keio University (No. 21009R) and all participants provided informed consent.

Patient and Public Involvement statement

There was no patient and public involvement in this study.

Definitions of variables

(1) Vaccine-related questions

To measure vaccine hesitancy, we asked respondents their vaccination intentions, based on response options: already vaccinated, willing to vaccinate, undecided, and unwilling to vaccinate. Following the definition of vaccine hesitancy [2], we operationally defined those who were undecided and unwilling to vaccinate as vaccine hesitant.

In instances where respondents hesitated to vaccinate, we additionally asked them about the reasons for the unacceptance of a vaccine and asked them to indicate if each reason mattered to them. Referring to previous investigations [33, 34], we identified 18 items, such as concerns about the vaccine's side effects, safety, efficacy, and other reasons.

(2) Independent variables

To account for the factors associated with vaccine hesitancy, as indicated by previous findings [3, 8-11], we obtained demographic, socioeconomic, health-related, and psychological information on each respondent.

The demographic and socioeconomic status of respondents included information on age, gender, co-resident family members, occupation, education, and

income. Respondents living with members with chronic illnesses, aged 65 or over, and aged 11 or younger may be more likely to vaccinate because they are considered vulnerable to infection or not eligible for COVID-19 vaccination in Japan. In terms of occupation, we used three categories of essential healthcare workers, frontline essential workers, and other workers, following existing definitions [35]. Educational attainment of respondents included three categories of high school or lower, junior college or vocational school, and university or higher. Income refers to annual household income, obtained as the median value in 19 ranges.

We also used two health measures of self-rated health and depressive symptoms measured by the Kessler Psychological Distress Scale (K10), which have been validated by previous studies [36, 37]. Higher scores indicate better health for the former scale, whereas lower scores indicate worse health for the latter.

Finally, we used the following items to measure psychological and behavioural factors. Time and risk preferences, which relate to individuals' responses to uncertain risks of vaccination and infection, were measured in the following two ways. The time preference was measured by the relative value of a larger later gain (13 months later) instead of a smaller immediate rewards (i.e. JPY 10,000 one month later) [38]. The risk preference was obtained as the sum of the responses to seven questions on risk attitudes measured using a seven-point Likert scale [39], which indicate higher scores representing more risk-loving. To measure respondents' perceived seriousness of COVID-19, we used the Fear of COVID-19 Scale [40, 41]. We defined respondents' numeracy as the number of correct answers to the same three questions proposed in a previous study [42].

Empirical strategy

To assess the determinants of vaccine hesitancy, the reasons for hesitating vaccination, and efficacies of the relaxation of public health restrictions on vaccine acceptance, we conducted the following three analyses.

(1) Determinants of vaccine hesitancy

We evaluated the association between vaccine hesitancy and its determinants, including demographic, socioeconomic, health, and psychological factors. In the base model, we analysed the association using a logit model with a dichotomised outcome (i.e. unwilling to vaccinate or undecided vs. willing to vaccinate or already vaccinated). To test the robustness of the results, we assessed the association using a three-level nominal outcome (unwilling to vaccinate vs. undecided vs. willing to vaccinate or already vaccinated).

(2) Reasons for vaccine hesitancy

We investigated the determinants of the reasons for vaccine hesitancy by analysing the association between demographic, socioeconomic, health, and psychological factors and each reason given by the individuals hesitating to vaccinate. We estimated the marginal effects of the factors for each reason using a logit model.

(3) Conjoint analysis: vaccine passport

To evaluate the association between the relaxation of public health restrictions by vaccine passports and vaccine acceptance, we utilised a conjoint experimental design [18, 43]. The conjoint experiment is useful in assessing the effects of varied attributes at different levels, reducing the number of necessary assignments using an orthogonal table.

Using this design, in a hypothetical situation, we asked each respondent whether they would vaccinate, assuming that some or all four public health restrictions are relaxed. The four public health restrictions included travel across prefectures, dining out at night, joining gatherings and events, and going out without face masks, which correspond to government requests in Japan.

Without the design, we would need to assign 16 (= 2^4) questions to assess each attribute of vaccine passports to each respondent; however, we reduced assignments by half, as shown in Table 1.

<Table 1>

In the conjoint experiment, all respondents provided their vaccination intentions for each hypothetical vaccine passport. To account for potential non-random variance across respondents arising from repeated measures, we fitted population-average panel-data models using the method of generalised estimating equations [44], estimating robust standard errors, and considering logit models with binominal distributions of outcomes.

All analyses were conducted using Stata MP, version 17.1 (StataCorp LLC, College Station, United States of America).

Results

Descriptive statistics

Table 2 summarises the descriptive statistics of the sample. Of a total of 5,000 respondents, about 30% hesitated to vaccinate (i.e. unwilling to vaccinate: 12.5% and undecided: 17.9%). Vaccination intentions and status can change over time due to various factors, such as infection situation and vaccine availability. At the time of the survey, about 38% of the Japanese population had at least one dose of the COVID-

19 vaccine[5], health professionals and older adults being prioritized. The proportion of the vaccinated population was almost identical to that of our sample (36.6%), indicating that our sample reflects the Japanese context well.

<Table 2>

Table 3 presents the reasons for vaccine hesitancy among the individuals who hesitate to vaccinate. The most major concerns were the vaccine's side effects and safety (87%), as well as other reasons related to vaccine safety, preference, and mistrust being commonly reported by respondents.

<Table 3>

Determinants of vaccine hesitancy

Table 4 shows the determinants of vaccine hesitancy. Compared to those aged 45–49, younger people aged 25–44 were likely to hesitate to vaccinate, resulting in estimated odds ratios (ORs) ranging between 1.32 and 1.87, with 95% confidence intervals (CI) ranging from 1.01 to 2.44. Meanwhile, older adults aged 55–74 tended to accept vaccination, showing estimated ORs between 0.17 and 0.67 with 95% CI from 0.11 to 0.89. Female respondents tended to express vaccine hesitancy more than their male counterparts (OR: 1.18, 95% CI: 1.02 – 1.37). Additionally, those living with older adults and members with chronic illness tended to accept vaccination with higher probabilities of 16–44% compared to their counterparts not living with these population categories.

Socioeconomic factors are also associated with vaccine hesitancy. Healthcare workers, frontline essential workers, and those performing paid work were likely to be non-vaccine-hesitant compared to non-employed individuals: the former two groups were more likely to accept vaccination, showing ORs of 0.23 (95% CI: 0.16–0.33) and

0.71 (95% CI: 0.59–0.86), respectively. Furthermore, higher education and income were associated with a lower likelihood of being vaccine-hesitant.

Those with poorer health, measured by self-rated health and the K10 depression scale, were less likely to hesitate to vaccinate by 18% (95% CI: 0.76–0.89) and 1% (95% CI: 1.00–1.02), respectively. Psychological and behavioural factors such as time preference and fear of COVID-19 were also predictors of vaccine hesitancy.

<Table 4>

To check the robustness of the results, we decomposed vaccine hesitancy into two groups: those unwilling to vaccinate and those who have not yet decided. Similar results were observed for the findings estimated from the binary outcomes (Appendix Table A-1).

Reasons for vaccine hesitancy

In Figure 1 and 2, we present the results of the analyses on the reasons related to the side effects and safety of the vaccine and vaccine mistrust, which were the most common. While we did not find remarkable heterogeneity across most factors, a higher numeracy was associated with vaccine hesitancy due to concerns about vaccine side effects and safety.

<Figure 1>

<Figure 2>

Additionally, the results for other reasons are shown in Appendix Figures A-1, A-2, A-3, and A-4. Again, we did not find systematic trends in the determinants of the reasons for vaccine hesitancy.

Effectiveness of vaccine passport

From the conjoint experiment, we observed that 45% of all the vaccine hesitant intended to accept vaccination when all public health restrictions were relaxed, while 18% intended so if no restrictions were relaxed.

In Figure 3, we present the estimation results for the association between the relaxation of each public health restrictions and vaccine acceptance, suggesting that relaxing all restrictions were effective in increasing vaccine acceptance by 4–10%. In particular, the relaxation of travel restriction across prefectures was the most effective, showing a 10% increase (95% CI: 9-11%) in vaccine acceptance, if permitted.

Moreover, we analysed the potential heterogeneity among younger people aged 44 or younger, who were more likely to be vaccine-hesitant in our previous analysis. We found that the results remained unchanged and these policies were effective for younger people.

<Figure 3>

Additionally, we conducted the following robustness tests. First, we excluded the respondents whose choices may have been nontransitive. Some individuals preferred not to vaccinate when an additional relaxation was offered, although they expressed their willingness to vaccinate with fewer options. Although this may suggest that they did not prefer to ease certain restrictions regardless of vaccination status, we re-analysed the association by excluding them. However, the results remained unchanged (Appendix Figure A-5). Second, we separately analysed respondents who were undecided and unwilling to vaccinate. Although marginal effects among those unwilling to vaccinate become smaller while the estimates undecided respondents became larger, we found that the relaxation of public health restrictions were evidently effective to increase vaccine acceptance (Appendix A-6). Third, we included respondents who intended to vaccinate earlier or have already been vaccinated, and

the same results were still observed (Appendix Figure A-7). Next, from among the individuals hesitating to vaccinate, we excluded those who provided a uniform answer to all options (i.e. all yes or no), the results remaining unchanged (Appendix Figure A-8). Finally, to relax the assumption of the independence of irrelevant alternatives, we estimated our main model by a multilevel mixed-effects logistic regression and confirmed the results were still robust (Appendix Figure A-9).

Stated and revealed preferences

About four months after this survey (i.e. between 10th and 20th of November 2021), we conducted a follow-up survey and obtained 4,367 responses out of 5,000 participants in the first wave (87.3%). For respondents who had not vaccinated yet at the first survey, we present descriptive statistics on vaccination status at the follow-up survey (Table 5). More than 90% of respondents who intended to vaccinate actually receive it while smaller proportions among those undecided and unwilling to vaccinate did so. About 29% of undecided and 69% of unwilling individuals remain vaccine hesitant in the follow-up survey.

Discussion

This study primarily assessed whether easing public health restrictions after vaccination increases vaccine acceptance, as well as investigated determinants of vaccine hesitancy and reasons for vaccine hesitancy. As the first study to explore the effectiveness of the relaxation of public health restrictions, by decomposing what can be permitted by vaccination, we obtained three main findings. First, in line with previous findings [3, 8-11], our analysis suggests that demographic, socioeconomic, health-related, and psychological factors predict vaccine hesitancy. In particular,

younger age seems to be the strongest predictor of vaccine hesitancy, while other factors, such as gender and socioeconomic factors, were also associated with vaccine hesitancy. Second, concerns about the side effects and safety of the COVID-19 vaccine, as well as mistrust of vaccines and the government in general, were dominant reasons for vaccine hesitancy. Meanwhile, we did not observe remarkable heterogeneity in the association between age, which was found to be a strong predictor of vaccine hesitancy, and the reasons for vaccine hesitancy. Third, we found that vaccination acceptance increases by easing public health restrictions, especially travel restrictions across prefectures. This result was particularly evident among younger people, who had higher probabilities of vaccine hesitancy than their older counterparts.

One reason why younger people tend to hesitate to vaccinate is the expected balance between the costs and benefits of vaccination, as predicted by the health belief model and economic theory [7, 13]. Considering that younger people are less likely to develop severe COVID-19 symptoms than older people [16] and given the higher likelihood of the side effects of the vaccine (e.g. headache and fatigue) among them [17], they could decide not to vaccinate from a utilitarian perspective. While we did not observe remarkable trends for the association between age and the reasons for hesitating to vaccinate, vaccine safety and side effects were the most common reasons, which has also been reported by other studies [33, 34]. Moreover, we found that statistical numeracy predicts vaccine hesitancy due to the concerns about vaccine safety and side effects. This may suggest that, being related to prospect theory, statistical capacity is related to inconsistent preferences and overestimating health losses of vaccination [45].

Our study also suggests that vaccine passports, which allow citizens freedom

in their daily lives, could increase vaccine acceptance. In many countries, including Japan, individuals are subject to containment and closure policies by governments to curb the spread of the virus, which requires them to avoid non-essential activities, such as eating out, travelling, and mass gatherings. As stay-at-home orders and social distancing behaviours can deteriorate citizens' well-being and mental health through distress, boredom, loneliness, and social isolation [46], eliminating public health restrictions and returning to a normal life may be what many citizens are eager to attain.

Based on our findings, several policy implications can be drawn. First, information campaigns to convey accurate messages are extremely important to enhance the understanding and remove vaccine mistrust. Utilising behavioural insights, better designs on how to best communicate with people to enhance vaccine uptake are considered [23, 24]. Second, emphasising benefits other than health (e.g. the relaxation of public health restrictions), if applicable, may enhance vaccine acceptance. Even under the concerns about breakthrough infections, the overall public health benefits may be in surplus if and only if a rise in vaccine acceptance largely reduces severe symptoms and the mortality rate from infection given the confirmed safety of the vaccine by contributing to the establishment of herd immunity against COVID-19. The continuous evaluations and careful consideration of the efficacy, duration of effectiveness, and side effects of the vaccine, as well as potential public health impacts and ethical issues of vaccine passports are indispensable. With the uncertain duration of vaccine efficacy and the efficacy against new virus variants, it would be realistic to issue vaccine passports for a limited time, maintaining moderate infectious control measures. Furthermore, these types of passports must not be used to discriminate and eliminate those not vaccinating from society, allowing them to use alternative services, such as a certificate for a negative COVID-19 test result.

In this study, we first provided evidence on the effectiveness of vaccine passports to relax the public health restrictions, decomposing the activities allowed by passports, on reducing vaccine hesitancy. Nevertheless, several limitations should be noted due to caveats. First, our study was based on a hypothetical experiment and not a real situation. Therefore, actual behaviour may diverge from the survey responses. Notwithstanding this limitation, our findings should still be helpful, based on previous reports that more than 80% of the stated and revealed preferences corresponded [47, 48]. Second, our findings are based on a single survey, in which the sample was obtained from registered panels that may not be identical to the general public. Although we utilised weights estimated by population structures by region, other factors than these could not be representative. Also, vaccination intentions may fluctuate due to the pandemic situation and the timing of the survey. Furthermore, our results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy can vary across countries. In Japan, compared to Western countries, the COVID-19 mortality rate is much lower [49], and government responses to the pandemic are less stringent [50]; hence, the attitude of the Japanese population toward the vaccine and vaccine passports availability may differ from other countries. Therefore, intertemporal and cross-national evidence needs to be accumulated through further studies.

Conclusions

In conclusion, this work offers encouraging findings regarding the vaccination intentions of the Japanese people. Although some individuals hesitate to get vaccinated against COVID-19, this can be reduced by mitigating concerns about vaccine safety and side effects throughout appropriate and effective information

campaigns. Additionally, the relaxation of public health restrictions, such as travel across prefectures, wearing face masks, and dining out at night, is effective in enhancing vaccine acceptance. To assist the progress toward herd immunity, the feasibility of vaccine passports needs to be sufficiently assessed by taking the ethical issues of the passports and public health impacts of the relaxation of restrictions into careful consideration.

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a. Contributorship statement

Okamoto, Kamimura, and Komamura conceptualised the study and were engaged in the data collection. Okamoto and Kamimura conducted analyses, which was further refined and finalised by Okamoto. Komamura also provided critical comments to refine analysis. Okamoto prepared a first draft, which was reviewed by Kamimura and Komamura.

b. Competing interests

We declare no conflicts of interest associated with this study.

c. Funding

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d. Data sharing statement: The data underlying this article cannot be shared publicly for the privacy of individuals that participated in the study. We did not obtain consents from respondents to make the data open.

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Table 1. Conjoint experimental design

	Available relaxations of restrictions by vaccine passports				Vaccine intensions
	Travel across prefectures	Dining out after 8 p.m.	Joining gatherings and events	Going out without face masks	Yes / No
Pattern A	×	×	×	×	
Pattern B	×	×	○	○	
Pattern C	×	○	×	○	
Pattern D	×	○	○	×	
Pattern E	○	×	×	○	
Pattern F	○	×	○	×	
Pattern G	○	○	×	×	
Pattern H	○	○	○	○	

Table 2. Descriptive statistics (n = 5,000)

Variable	Mean or proportion	Standard deviation
Vaccine intentions: No	12.5%	
Undecided	17.9%	
Yes	33.1%	
Already vaccinated	36.6%	
Age	48.40	14.80
Female	50.3%	
Co-residence: Aged 65 or older	33.3%	
Aged 11 or younger	14.4%	
Chronic illness	25.0%	
Occupation: Healthcare worker	6.4%	
Frontline essential workers	26.3%	
Other occupations	31.8%	
Not employed (Ref.)	35.5%	
Education: High school or lower (Ref.)	31.2%	
Junior college or vocational	19.5%	
University or higher	49.2%	
Household income (million JPY)	5.60	3.78
Self-rated health	3.52	1.02
K10 depression scale	17.95	9.18
Numeracy	1.58	0.78
Time preference	21.08	16.21
Risk preference	27.85	8.3
Fear of COVID-19	19.63	5.46
Residential area: Hokkaido	4.6%	
Tohoku	5.9%	
Kanto	26.1%	
Chubu	14.9%	
Kinki	14.3%	
Chugoku	19.3%	
Shikoku	6.7%	
Kyushu	8.0%	

Table 3. Reasons for vaccine hesitancy

Reasons	%
Concern about side effects and safety of the vaccine	87%
Plan to wait and see if it is safe and may get it later	79%
Concern that the vaccine is being developed too quickly	73%
Plan to use masks/other precautions instead	69%
Do not trust the government	67%
Do not like vaccines	63%
Do not like needles	48%
Do not know I needed a vaccine against COVID-19	45%
The vaccine could give me COVID-19	37%
The vaccine will not work	31%
I will not need vaccinate because vaccination of other people will establish herd immunity	29%
Vaccination site is far	28%
COVID-19 is not a serious illness	26%
Too busy to visit a vaccination site	25%
Had COVID-19 and should be immune	11%
Doctor has not recommended a COVID-19 vaccine to me	11%
Pregnant	7%
For religious reasons	5%

Note: Percentages among 1,518 respondents hesitating vaccination.

Table 4. Determinants of vaccine hesitancy

Vaccine hesitancy	Odds ratio	95%CI
Age (Ref. 45-49): 20-24	1.13	0.82 - 1.58
25-29	1.87**	1.44 - 2.44
30-34	1.67**	1.26 - 2.21
35-39	1.83**	1.42 - 2.36
40-44	1.32*	1.01 - 1.73
50-54	0.79	0.60 - 1.04
55-59	0.67**	0.50 - 0.89
60-64	0.40**	0.30 - 0.53
65-69	0.17**	0.11 - 0.26
70-74	0.18**	0.12 - 0.27
Female	1.18*	1.02 - 1.37
Co-residence: Aged 65 or older	0.84*	0.71 - 1.00
Aged 11 or younger	0.92	0.76 - 1.13
Chronic illness	0.56**	0.47 - 0.67
Occupation: Healthcare worker	0.23**	0.16 - 0.33
Frontline essential workers	0.71**	0.59 - 0.86
Other occupations	0.80*	0.67 - 0.95
Education: Junior college or vocational	0.85	0.70 - 1.03
University or higher	0.68**	0.58 - 0.80
Household income	0.95**	0.93 - 0.97
Self-rated health	0.82**	0.76 - 0.89
K10 depression scale	1.01**	1.00 - 1.02
Statistical literacy	0.96	0.87 - 1.05
Time preference	1.01**	1.00 - 1.01
Risk preference	1.00	0.99 - 1.01
Fear of COVID-19	0.97**	0.96 - 0.99
Constant	3.91**	2.07 - 7.42
Observations	5,000	

Note: Vaccine hesitancy refers to individuals who were undecided and unwilling to vaccinate; The outcome reference is 'Willing to vaccinate or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Table 5. Stated and revealed preferences

Wave1 \ Wave2	Vaccinated	Intend to vaccinate	Undecided	Unwilling to vaccinate	Total
Intend to vaccinate	94.9%	2.9%	1.3%	1.0%	1,424
Undecided	66.3%	4.5%	17.5%	11.8%	756
Unwilling to vaccinate	29.0%	1.3%	13.8%	55.9%	538
Total	73.9%	3.0%	8.2%	14.9%	2,718

Note: Wave1 was conducted between 21–23 July 2021, while Wave2 was held between 10-20 November 2021 as a follow-up survey of Wave1.

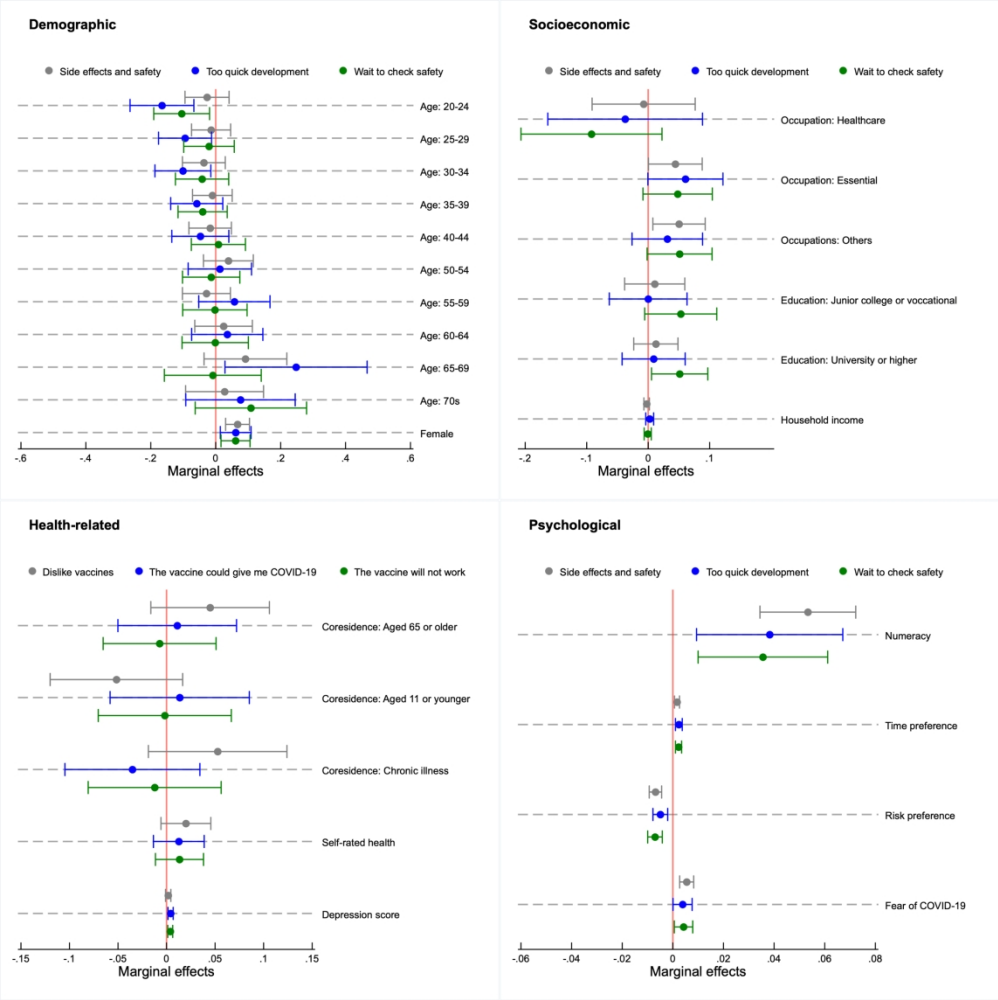

Figure 1. Determinants of reasons for vaccine hesitancy: Side effects and safety

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group.

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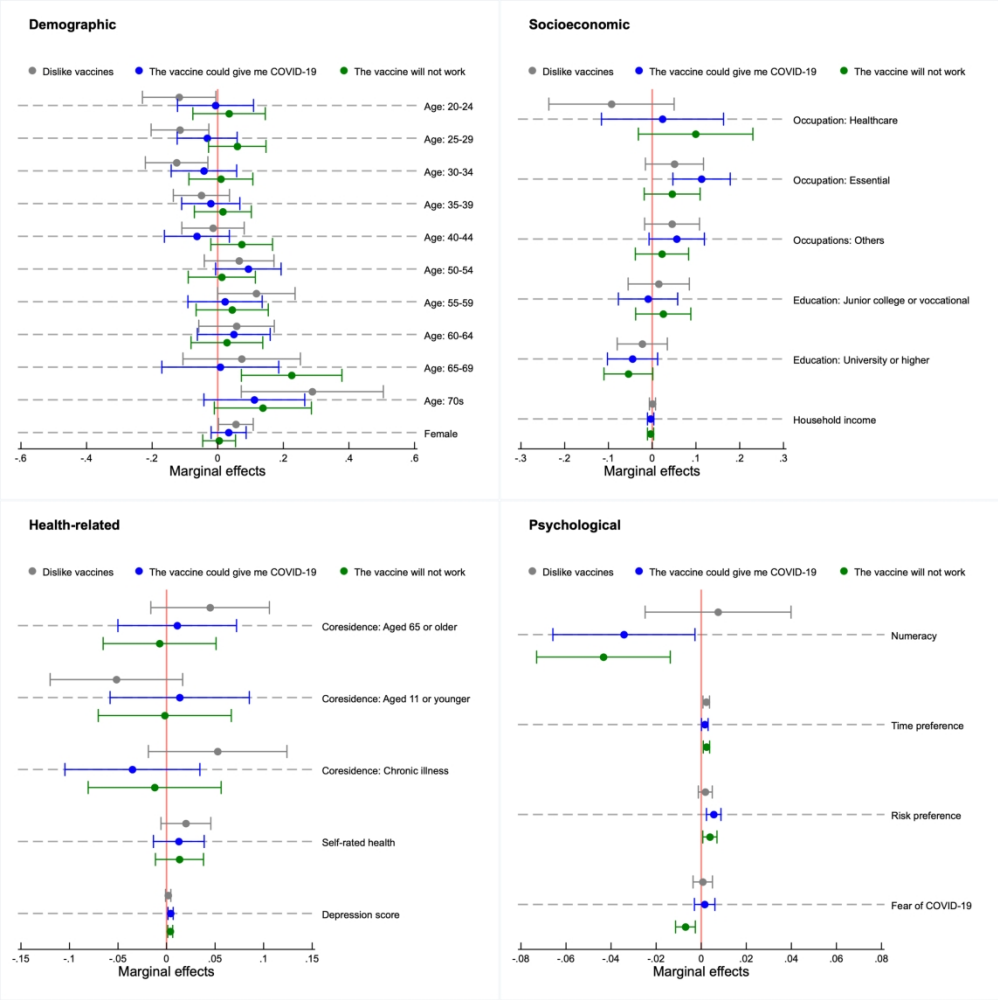

Figure 2. Determinants of reasons for vaccine hesitancy: Vaccine mistrust

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group.

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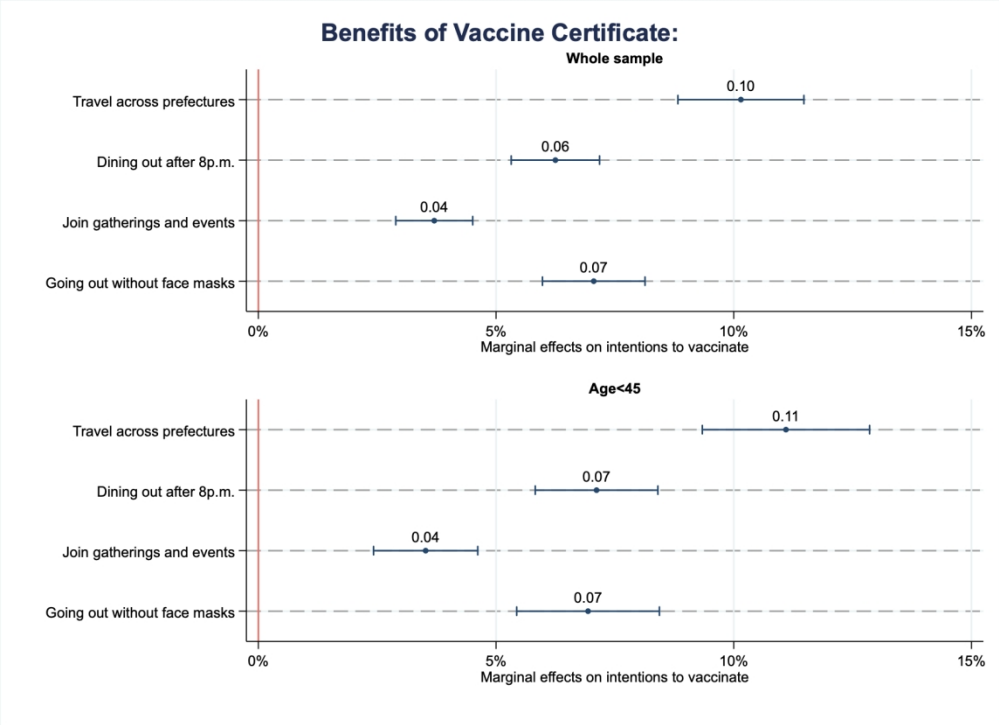

Figure 3. Effectiveness of vaccine passport

Note: Estimates among individuals who were undecided and unwilling to vaccinate (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

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Supplementary Material for
Vaccination or restriction?: COVID-19 vaccine hesitancy and vaccine passports

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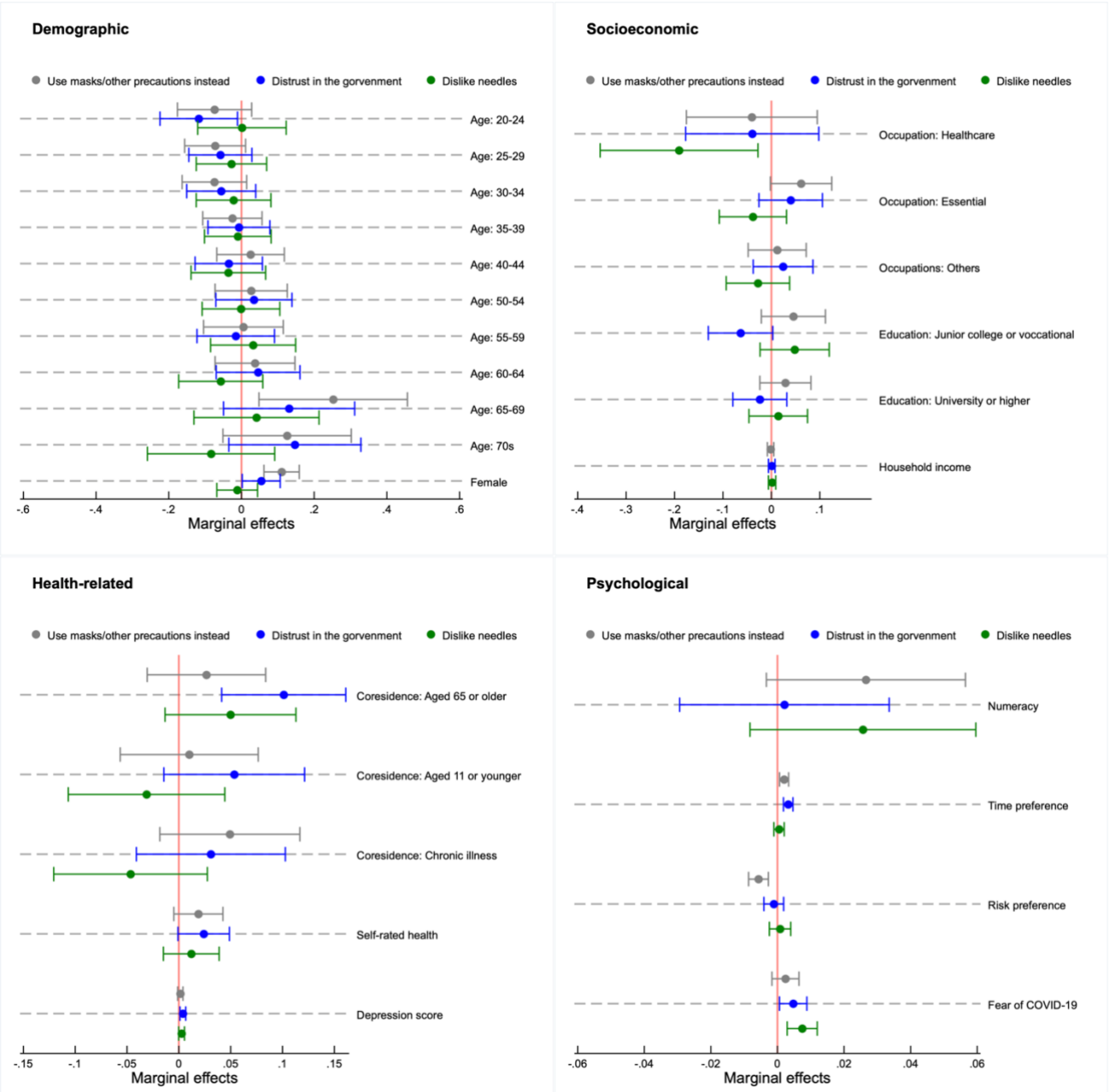
Appendix Table A-1. Determinants of vaccine hesitancy

	Will not vaccinate		Undecided	
Vaccine hesitancy	Relative risk ratios	95%CI	Relative risk ratios	95%CI
Age (Ref. 45-49): 20-24	1.48	0.95 - 2.30	0.94	0.63 - 1.41
25-29	1.97**	1.36 - 2.85	1.83**	1.35 - 2.47
30-34	2.08**	1.40 - 3.09	1.47*	1.07 - 2.03
35-39	2.22**	1.55 - 3.18	1.63**	1.22 - 2.19
40-44	1.46	0.99 - 2.15	1.25	0.92 - 1.70
50-54	0.87	0.58 - 1.29	0.75	0.55 - 1.04
55-59	0.89	0.59 - 1.35	0.55**	0.38 - 0.78
60-64	0.53**	0.35 - 0.79	0.33**	0.23 - 0.47
65-69	0.24**	0.13 - 0.42	0.14**	0.08 - 0.23
70-74	0.30**	0.18 - 0.51	0.11**	0.07 - 0.20
Female	1.08	0.88 - 1.32	1.26**	1.06 - 1.51
Co-residence: Aged 65 or older	0.75*	0.60 - 0.95	0.91	0.74 - 1.11
Aged 11 or younger	0.68*	0.50 - 0.92	1.10	0.88 - 1.38
Chronic illness	0.53**	0.41 - 0.68	0.59**	0.47 - 0.73
Occupation: Healthcare worker	0.26**	0.16 - 0.43	0.20**	0.13 - 0.33
Other essential workers	0.56**	0.43 - 0.73	0.83	0.67 - 1.04
Other occupations	0.70**	0.55 - 0.89	0.88	0.71 - 1.09
Education: Junior college or vocational	0.82	0.63 - 1.07	0.87	0.69 - 1.10
University or higher	0.60**	0.48 - 0.75	0.74**	0.61 - 0.90
Household income	0.96*	0.94 - 0.99	0.94**	0.92 - 0.97
Self-rated health	0.79**	0.71 - 0.88	0.85**	0.78 - 0.92
K10 depression scale	1.01**	1.00 - 1.03	1.01	1.00 - 1.02
Statistical literacy	0.85**	0.75 - 0.96	1.05	0.94 - 1.17
Time preference	1.01*	1.00 - 1.01	1.01*	1.00 - 1.01
Risk preference	1.00	0.99 - 1.02	0.99	0.98 - 1.00
Fear of COVID-19	0.95**	0.93 - 0.97	0.99	0.98 - 1.01
Constant	3.01*	1.25 - 7.22	1.35	0.64 - 2.85
Observations	5,000			

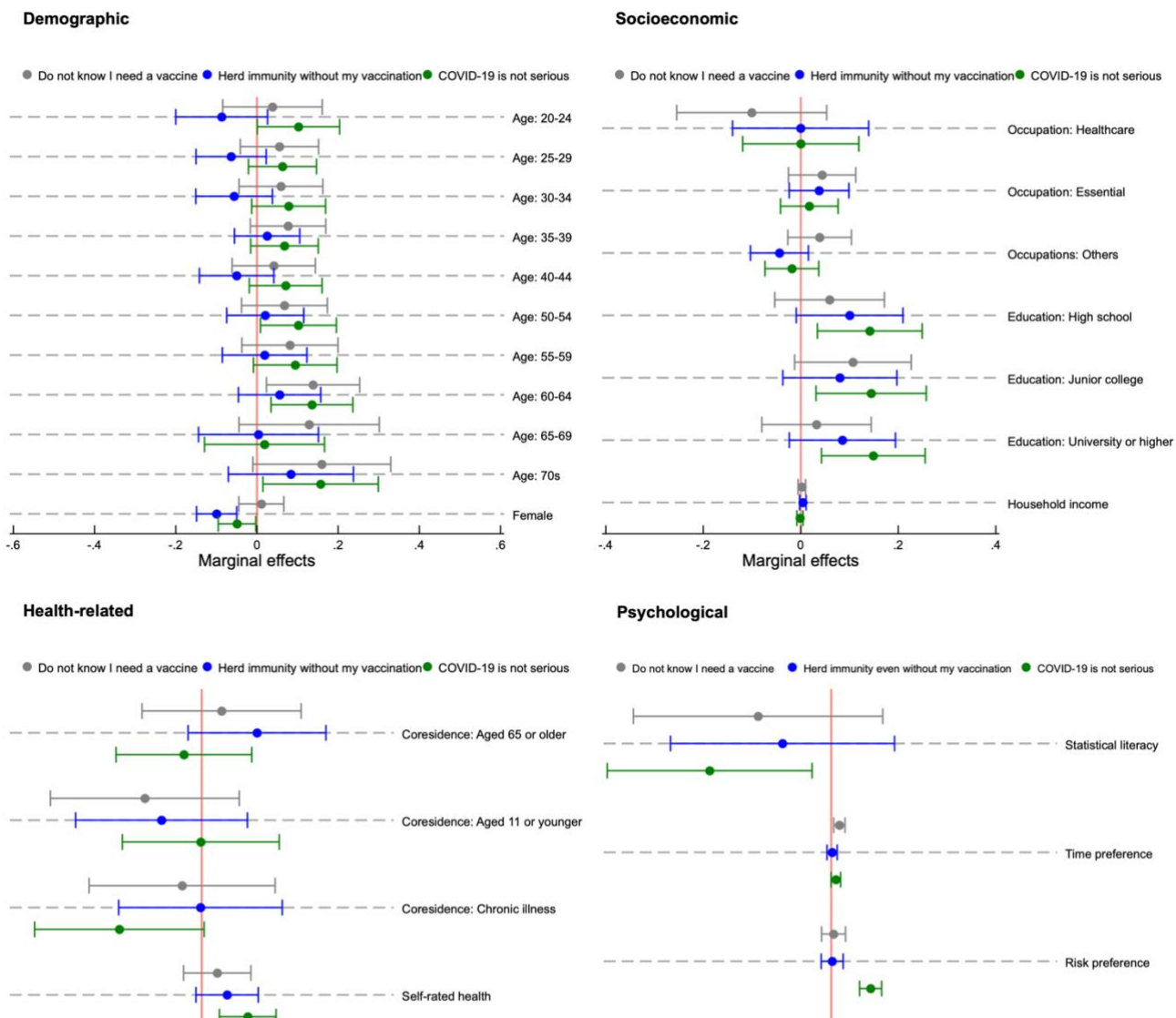
Note: The outcome reference is 'Willing to vaccinate or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Appendix Figure A-1. Determinants of reasons for vaccine hesitancy: Other mistrust



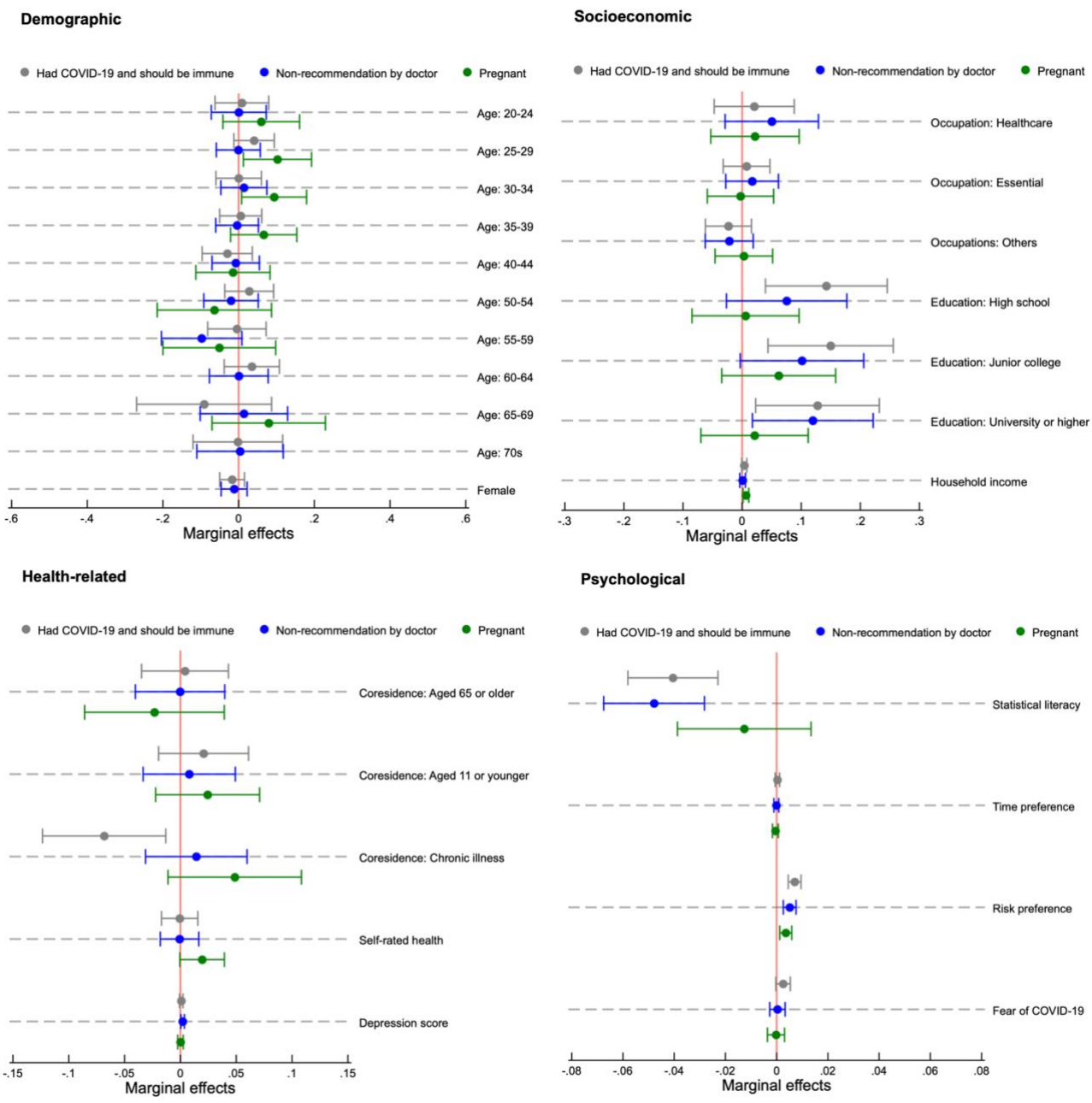
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group.

Appendix Figure A-2. Determinants of reasons for vaccine hesitancy: Attitudes toward COVID-19



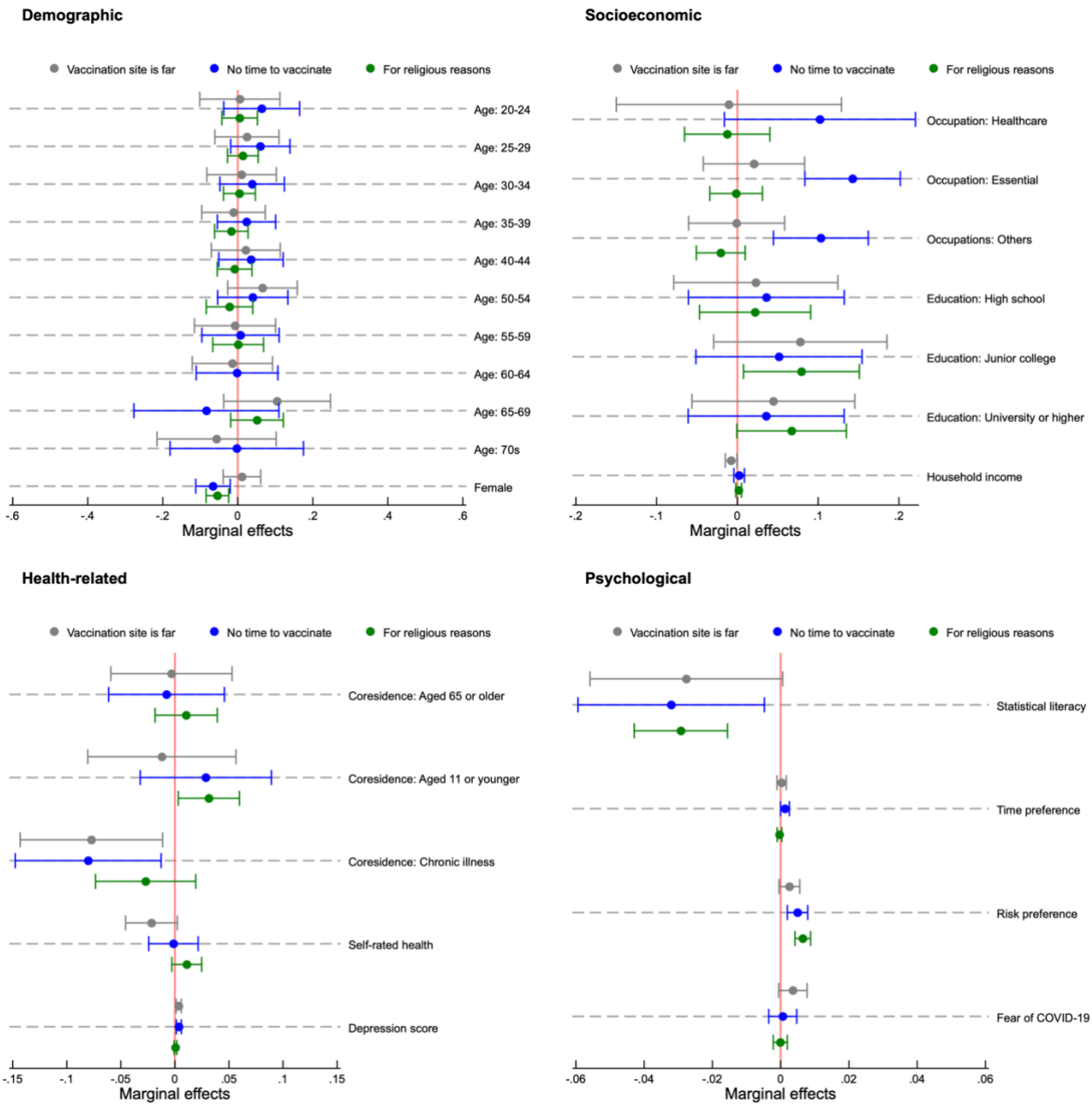
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-3. Determinants of reasons for vaccine hesitancy: Health-related reasons



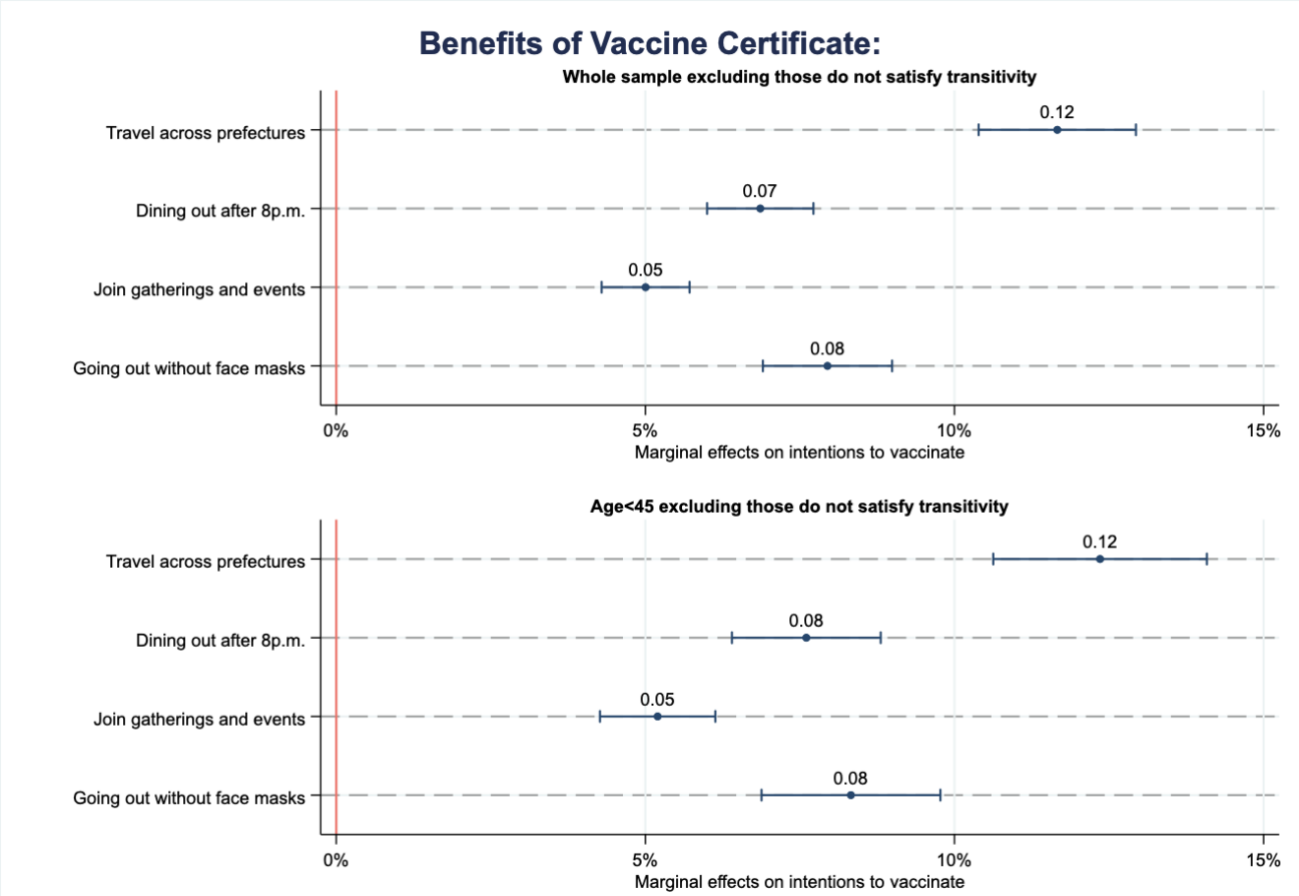
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-4. Determinants of reasons for vaccine hesitancy: Other reasons



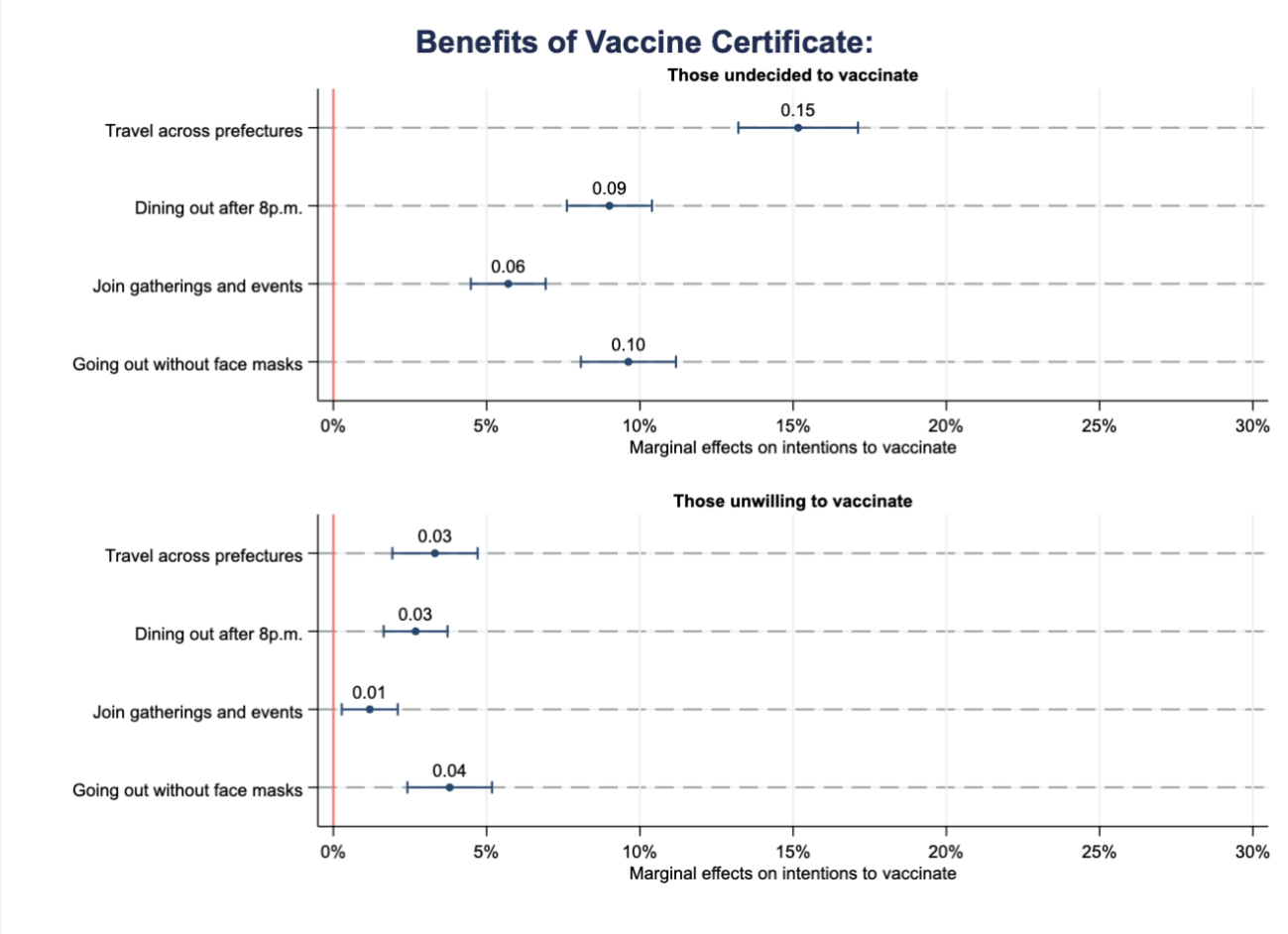
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-5. Vaccine passport: Exclude those with non-transitive preferences



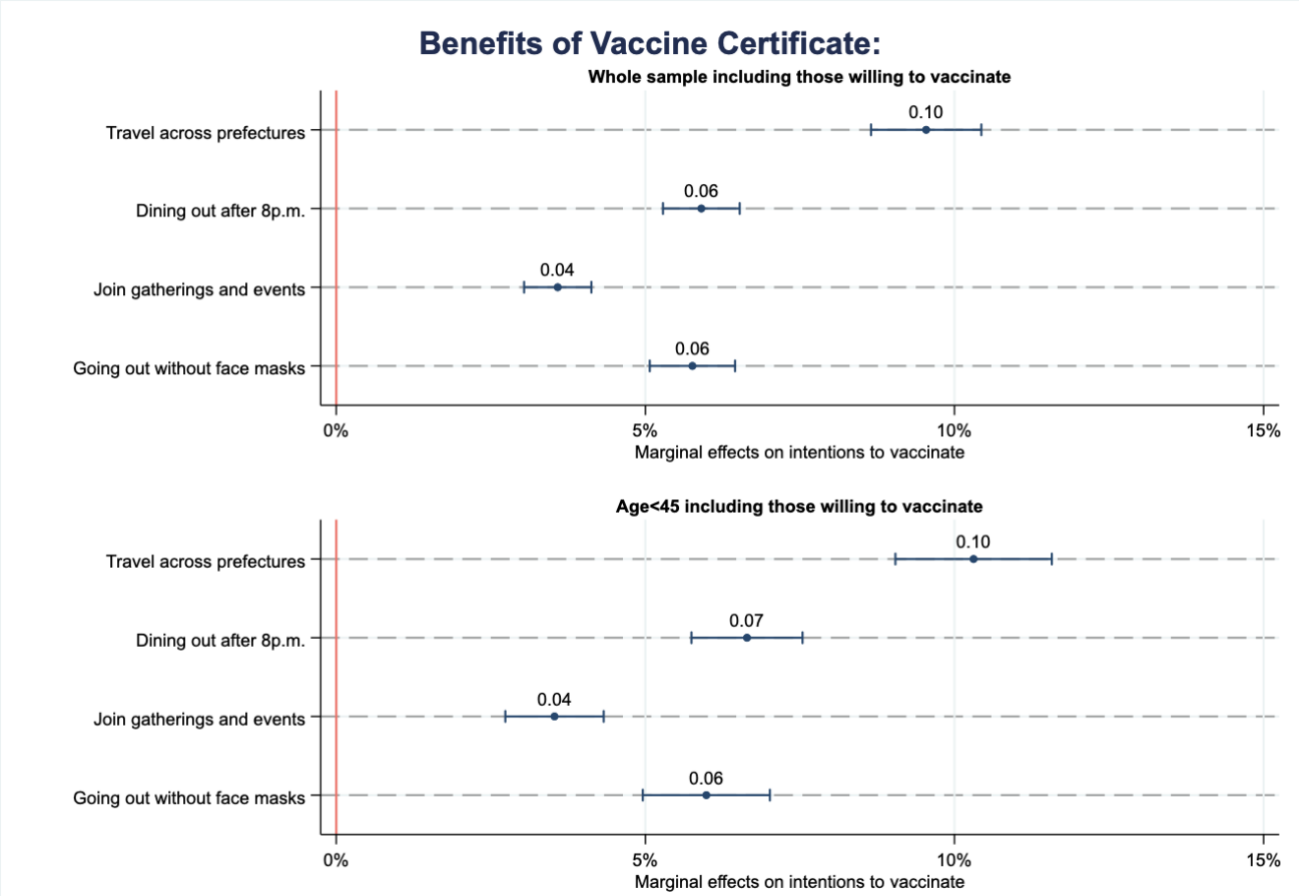
Note: Estimates among individuals who were undecided and unwilling to vaccinate, excluding those who did not satisfy transitivity of the vaccine preference (n= 1,416 for all age groups and n= 815 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

Appendix Figure A-6. Vaccine passport: Separate analyses of those undecided and unwilling to vaccinate



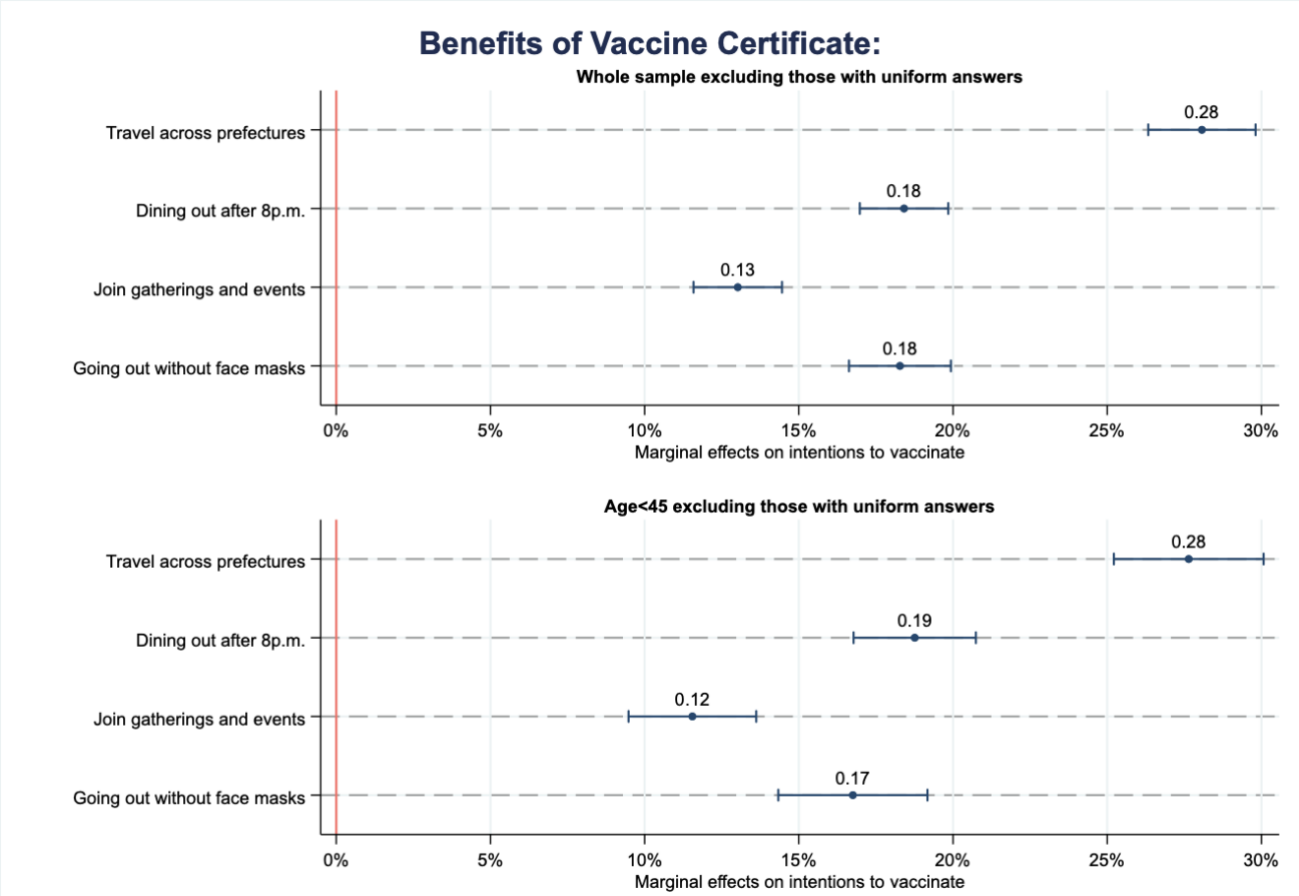
Note: Estimates among individuals who were unwilling to vaccinate (n= 894 for those undecided to vaccinate and n= 624 for those unwilling to vaccinate); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

Appendix Figure A-7. Vaccine passport: Include those willing to vaccinate



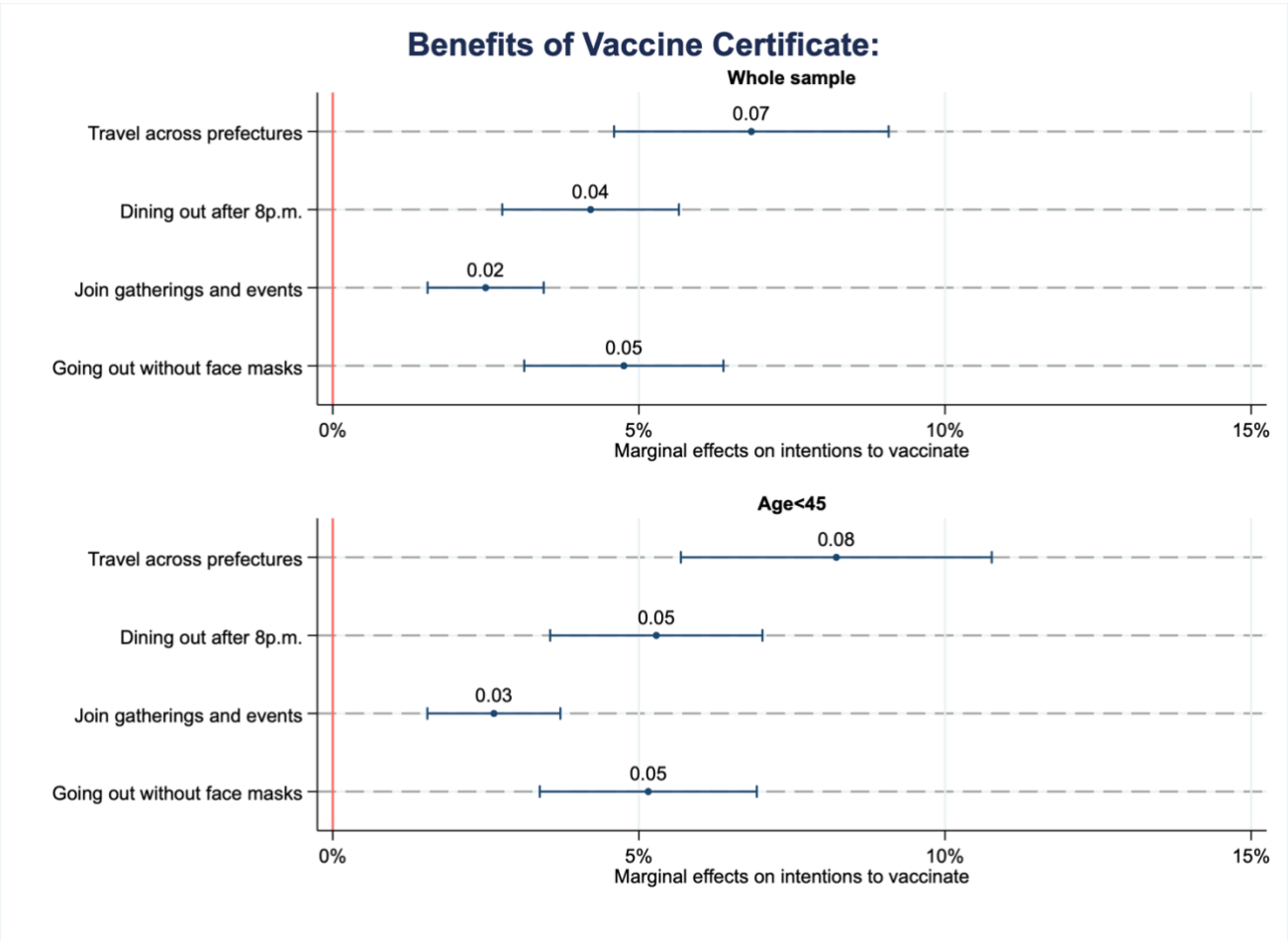
Note: Estimates among individuals who have not vaccinated yet, including 'Unwilling,' 'Undecided,' and 'Willing' (n= 3,171 for all age groups and n= 1,644 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

Appendix Figure A-8. Vaccine passport: Exclude uniform individuals



Note: Estimates among individuals who were undecided and unwilling to vaccinate, excluding those who provided uniform answers regarding their vaccination intentions regardless of available options (n= 1,531 for all age groups and n= 754 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

Appendix Figure A-9. Vaccine passport: Estimates by multilevel mixed-effects logistic regression



Note: Estimated by multilevel mixed-effects logistic regression with random intercepts by individuals among those who were undecided and unwilling to vaccinate (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Full results are available upon request.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-9
Objectives	3	State specific objectives, including any prespecified hypotheses	9
Methods			
Study design	4	Present key elements of study design early in the paper	10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	10
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	11, 12
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*10-12*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-14
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13, 14
		(*b*) Describe any methods used to examine subgroups and interactions	13, 14
		(*c*) Explain how missing data were addressed	NA
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	10

	(*e*) Describe any sensitivity analyses	14-17

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*NA*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*NA*
		Cross-sectional study—Report numbers of outcome events or summary measures	*14*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-18
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	18-19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20, 21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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COVID-19 vaccine hesitancy and vaccine passports: A conjoint experiment in Japan

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COVID-19 vaccine hesitancy and vaccine passports: A conjoint experiment in Japan

Short title: COVID-19 vaccine hesitancy and vaccine passports

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Abstract

Objectives: While the development of vaccines against the novel coronavirus (COVID-19) brought hope of establishing herd immunity and ending the global pandemic, vaccine hesitancy can hinder the progress towards herd immunity. In this study, by analysing the data collected when citizens undergo public health restrictions due to the pandemic, we assess the determinants of vaccine hesitancy, reasons for hesitation, and potential effectiveness of vaccine passports used to relax public health restrictions on mitigating vaccine hesitancy.

Methods: We carried out the study in July 2021 by using an online survey that includes a conjoint experiment of a demographically representative sample of 5,000 Japanese adults aged 20–74.

Results: We found that about 30% of respondents did not intend to get vaccinated or had not yet decided, with major reasons for vaccine hesitancy relating to concerns about the safety and side effects of the vaccine. In line with previous findings, younger age, lower socioeconomic status, and psychological and behavioural factors such as weaker COVID-19 fear were associated with vaccine hesitancy. Easing of public health restrictions such as travel, wearing face masks, and dining out at night was associated with an increase in vaccine acceptance by 4–10%. Moreover, we found that more than 90% of respondents who intended to get vaccinated actually received it while smaller proportions among those undecided and unwilling to get vaccinated did so.

Conclusion: With a major concern about vaccine safety and side effects, interventions to mitigate against these may help reduce vaccine hesitancy. Moreover, when citizens are imposed with restrictions, vaccine passports that increase their freedom may be helpful to increase vaccination rates. However, the feasibility of vaccine passports

needs to be sufficiently assessed, taking the ethical issues of passports and the public health impacts of the relaxation of restrictions into careful consideration.

Strengths and limitations of this study

- This study includes timely data on COVID-19 vaccine hesitancy, obtained from a demographically representative sample of 5,000 Japanese adults.
- The data were collected in July 2021 when the citizens were imposed with public health restrictions.
- A conjoint experiment allows assessing the effectiveness of easing public health restrictions on vaccine acceptance.
- Actual behaviour may diverge from the survey responses or fluctuate due to the pandemic situation and the timing of the survey.
- Results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy can vary across countries.

Introduction

After a period when nations have managed to curb the spread of the new coronavirus disease (COVID-19), mainly by non-pharmaceutical interventions such as containment and closure policies, the development of COVID-19 vaccines brought hope that the pandemic may end soon. Although the degree and duration of vaccine efficacy as well as the efficacy against new virus variants remain unconfirmed, widespread vaccination can contribute to establishing herd immunity against COVID-19. While the required proportions of individuals with immunity could vary by country (e.g. due to demographic structure and frequency of human contact), it is estimated that approximately 70% of the population needs immunity to achieve herd immunity against COVID-19, which would require more than 30 million deaths worldwide due to natural infection[1]. Therefore, global vaccination is a necessary step to end the pandemic.

However, vaccine hesitancy, defined as a 'delay in acceptance or refusal of vaccines despite availability of vaccine services' by a working group advising the World Health Organization[2], can hinder achieving herd immunity. The findings of systematic reviews and meta-analyses suggest that the vaccine acceptance rates are approximately 60–75% but show large discrepancies across regions, months of studies, and whether an answer of 'unsure' is available to survey respondents[3 4]. Together with the global disparities in vaccine availability for COVID-19, full vaccination rates are considerably low, and only approximately a third of the world population had received at least one dose of a vaccine against COVID-19 by August 2021[5]. While this low vaccine uptake may be due to many reasons, including individual preferences and other factors, such as system failures, identifying why people are reluctant to be vaccinated is important.

Whether an individual accepts vaccination is a consequence of a complex decision-making process, which occurs on the continuum between complete acceptance and refusal[2]. The above-mentioned working group developed the 'three Cs vaccine hesitancy model', which comprises confidence, complacency, and convenience, indicating that historic, socio-cultural, environmental, health system/institutional, economic, or political factors, as well as personal perception and vaccine/vaccination characteristics influence vaccine hesitancy. Moreover, from a utilitarian perspective, voluntary vaccinations can deviate from the social optimum owing to the positive externalities of vaccinated individuals; hence, Pigouvian subsidies, external regulations, or strategies to improve vaccine awareness are needed, depending on the nature of vaccine-preventable diseases and vaccines[6 7].

Therefore, it is important to understand the reasons for COVID-19 vaccine hesitancy, in addition to strategies to raise the vaccination rates. In the following section, we review the literature on the determinants of COVID-19 vaccine hesitancy.

Literature on COVID-19 vaccine hesitancy

(1) Socio-demographic factors

Given the concerns of the increasing hesitancy towards COVID-19 vaccination, many empirical studies have hitherto assessed factors associated with COVID-19 vaccine hesitancy[3 8-11]. These studies suggest that many empirical papers find that older people compared to their younger counterparts and men compared to women are more likely to accept a COVID-19 vaccine. Older people are susceptible to the disease, and while men and women can decline vaccination for various reasons, the differences in perceived risks, efficacies, and knowledge may inform these gender differences[11]. In addition to age and gender, educational attainment is identified as the most frequent

predictor, with higher acceptance among people with higher education levels[3]. While highly educated individuals can be vaccine-hesitant because of the influence of social groups and other authorities, education may play an important role in understanding disease severity and vaccination benefits[11].

(2) Psychological and behavioural factors

Vaccination is a consequence of one's utility maximisation, considering costs and benefits. Based on the health belief model, by modifying socio-demographic factors, individuals can decide whether to be vaccinated as a reflection of their personal beliefs about a disease and its preventive measures, such as susceptibility, severity, benefits, barriers, and self-efficacy[12 13]. A systematic review identifies that vaccine acceptance is higher among those with greater perceived risk, threat, vulnerability, and susceptibility to infection[8 9]. Furthermore, the beliefs about the vaccine are predictors of vaccine hesitancy, including mistrust in its safety or efficacy and conspiracy beliefs, which can be induced by low health literacy and negative information in the media[8].

Together with one's perceptions regarding vaccines and infection, individual preferences matter for health-related decision-making, including vaccination[14 15]. Time preference affects one's vaccination intentions because individuals will benefit from the vaccination in the future, despite having to bear its present costs. Therefore, those discounting future benefits would lead them to decide not to be vaccinated. Moreover, the attitudes toward risks are attributed to vaccination decision-making, that is, risk-averse individuals would feel conflicted between the risk of infection without vaccination and the vaccines' side effects. This would explain why younger people tend to be vaccine-hesitant, considering they are less likely to develop symptoms than their older counterparts[16] and have more frequent side effects[17]. In addition to

individuals' attributes and beliefs, vaccine characteristics are important determinants of vaccination intention, being highly relevant to individuals' perceptions and preferences for vaccines. In particular, individuals prefer vaccines with higher efficacy, longer duration of disease protection, and safety (that is, none or few adverse effects)[8 18].

Vaccination campaigns

To increase vaccination rates, considering the determinants of vaccine hesitancy discussed above and vaccine characteristics, potential strategies would include removing the (mis)perceived effectiveness and risks of vaccination and infection, minimising the costs associated with vaccination (i.e. out-of-pocket payments and opportunity cost), and increasing the benefits of vaccination by providing various incentives. In fact, several approaches, such as communication, financial and non-financial incentives, and reminder-recall interventions, have been adopted and evaluated so far[19 20].

Vaccination campaign frameworks have also been adopted to increase COVID-19 vaccination uptake. Aiming at a better understanding of the population for COVID-19 vaccines, public organisations disseminate information about the efficacy and safety of vaccines[21 22]. Additionally, a study suggests that emphasising the benefits of vaccination and inducing feelings of vaccine ownership are useful[23 24], thus suggesting the importance of information campaigns. In some countries, the convenience of vaccination locations is enhanced by providing these services within the areas of citizens' daily lives, such as train stations and supermarkets[25 26]. Furthermore, the incentives towards vaccination attract the attention of some policymakers[27], although their effectiveness remains inconclusive and may depend on

how incentives are given[28 29].

With remaining ethical concerns, 'vaccine passports', which denote certifications of vaccinations to fully or partially exempt vaccinated individuals from public health restrictions[30 31], are considered in many regions. The core rationale of vaccine passports is that public health restrictions due to the pandemic should be tailored to respond to public demands for the relaxation of the restrictions, when the scheme would be safe for at least some individuals. Despite these relative merits of vaccine passports, this scheme may work negatively for some individuals as requiring certifications to re-engage in social activities can essentially be a violation of individual freedom of choice[31]. While only a limited number of related studies are available, the freedom allowed by vaccine passports can affect vaccine acceptance and preference both positively and negatively: A study found that more freedom allowed by vaccination can increase vaccination uptake[29 32]. In contrast, some studies suggest that people do not prefer vaccination used as permission to engage in social activities[33 34], and thereby vaccine passports could be viewed negatively among some socio-demographic groups[32]. Despite the concern about `breakthrough infections', it would be worth considering the applicability of vaccine passports if and only if the passports largely contribute to achieving herd immunity against COVID-19 by increasing vaccine acceptance.

Literature gaps and aims of this study

Previous studies have documented the determinants of vaccine hesitancy by analysing the association of socio-demographic, psychological, and vaccine characteristics with vaccine intentions. Meanwhile, the evidence on how to increase COVID-19 vaccine acceptance remains scarce. In alignment with the policies in

several regions, the evidence on communication strategies and the incentives for reducing vaccine hesitancy have gained increasing attention, as discussed above, while the effectiveness of vaccine passports in raising vaccine acceptance has been limited. While countries such as Israel, France, and Italy attempt to utilise vaccine passports, other countries may also consider similar schemes to return to a 'normal life'. If so, it is immensely important to accelerate herd immunity by reducing avoidable vaccine hesitancy, to which the benefits of the vaccine passports may contribute. However, whether vaccine passports can contribute to increasing vaccination uptake is debatable.

Therefore, by analysing the data obtained when the citizens were exposed to public health restrictions, we assessed the effectiveness of easing public health restrictions by vaccine passports based on our analysis of a conjoint experiment. By decomposing the freedom factors allowed by the passport based on government regulations, we first evaluate an effective type of relaxation of public health restrictions to increase vaccine acceptance, which would be useful for health policymakers to design vaccine passports and curate compelling information on the benefits of vaccination for vaccine-hesitant individuals.

Methods

Data

The data come from a demographically representative sample of 5,000 Japanese adults aged 20–74 from an online survey conducted from 21–23 July 2021. In a non-experimental study setting that analyses the data by logistic regression, a previous study suggests that taking a minimum sample size of 500 is necessary to obtain reliable parameter estimates[35]: The sample size that we initially planned to collect was

well above this number, and thereby sufficient to obtain reliable estimates from an unbiased population. Survey respondents were recruited from registered panels of Cross Marketing Inc. To ensure that the survey is nationally representative regarding respondents' age and gender, we recruited respondents using quota sampling for each of the 14 age groups of the 2015 population census (that is, age categories of 20s, 30s, 40s, 50s, 60s, and early 70s by gender).

While we did not use regional quotas to recruit respondents, we addressed the potential non-representativeness arising from this by using weights for all analyses and estimated by population structures in each region. Specifically, we used eight categories for residential areas (i.e. Hokkaido, Tohoku, and Kanto except for the Tokyo Metropolitan Area, Tokyo Metropolitan Area, Chubu, Kinki, Chugoku, Shikoku, and Kyusyu) and eleven categories for each five-year age group from 20 to 74. The pandemic situation during the study period varied across regions, with most per-day COVID-19 new cases confirmed in Tokyo, Kanto (for example, Saitama and Kanagawa), Kinki (for example, Osaka), and Kyushu (for example, Okinawa).

About four months after this survey (i.e. between 10th and 20th of November 2021), we conducted a follow-up survey of the same respondents to compare their vaccination intention and status during the first and second waves, respectively. We obtained 4,367 responses out of 5,000 participants in the first wave (87.3%).

COVID-19 situation in Japan

During the survey, approximately 5,000 COVID-19 cases were reported per day as the number kept increasing. The state of emergency or quasi-state of emergency was declared in Tokyo, Okinawa, Saitama, Chiba, Kanagawa, and Osaka. In these areas, individuals and business owners were requested to refrain from engaging in non-

essential activities. In addition to the citizens in these prefectures, all the citizens in Japan were requested by the government to take preventive measures from the infection, such as wearing a face mask, hand washing, avoiding 'Three Cs' (i.e. closed spaces, crowded places, and close-contact settings), and ensuring adequate ventilation.

Ethical approval

This study was approved by the Institutional Review Board of the Institute of Economics Studies, Keio University (No. 21009R and 21011R). We obtained informed consent from the participants by providing information about the study and asking them to participate only if they understood the survey and agreed to join before answering the questionnaire.

Patient and Public Involvement statement

There was no patient and public involvement in this study.

Definitions of variables

(1) Vaccine-related questions

To measure vaccine hesitancy, we asked respondents their vaccination intentions, based on response options: already vaccinated, willing to be vaccinated, undecided, and unwilling to be vaccinated. Following the definition of vaccine hesitancy[2], we operationally defined those who were undecided and unwilling to vaccinate as vaccine-hesitant.

In instances where respondents hesitated to be vaccinated, we additionally asked them about the reasons for rejecting a vaccine and the importance of those

reasons. Referring to previous investigations[36 37], we identified 18 items, such as concerns about the vaccine's side effects, safety, efficacy, and other reasons.

(2) Independent variables

To account for the factors associated with vaccine hesitancy, as indicated by previous findings[3 8-11], we obtained demographic, socioeconomic, health-related, and psychological information on each respondent.

The demographic and socioeconomic status of respondents included information on age, gender, co-resident family members, occupation, education, and income. Respondents living with members with chronic illnesses, aged 65 or over, and aged 11 or younger would be more likely to be vaccinated because they are considered vulnerable to infection or not eligible for COVID-19 vaccination in Japan. In terms of occupation, we used three categories; essential healthcare workers, frontline essential workers, and other workers, following existing definitions by the Centers for Disease Control and Prevention[38]. Specifically, frontline essential workers include those working in manufacturing, wholesale/retail, transportation/shipping/postal services, education, primary industry, and critical infrastructure (i.e. electricity, gas, heat supplying services, and waterworks), whose works must be performed on-site. Educational attainment of respondents included three categories—high school or lower, junior college or vocational school, and university or higher. Income refers to annual household income, obtained as the median value in 19 ranges.

We also used two health measures of self-rated health and depressive symptoms measured by the Kessler Psychological Distress Scale (K10), which have been validated by previous studies[39 40]. Higher scores indicate better health for the

former scale, whereas lower scores indicate worse health for the latter.

Finally, we used the following items, identified as predictors of one's preventive behaviours, to measure psychological and behavioural factors: to measure respondents' perceived seriousness of COVID-19, we used the Fear of COVID-19 Scale[41 42]. Time and risk preferences, which relate to individuals' responses to uncertain risks of vaccination and infection, were measured in the following two ways: the time preference was measured by a question, 'If you were to receive some funds in 13 months, instead of obtaining it in 1 month, how much is the lowest amount that would be adequate for your needs? [43]' The risk preference was obtained as the sum of the responses to seven questions on risk attitudes measured using a seven-point Likert scale[44], which indicates higher scores representing higher risk-taking.

To measure respondents' ability to understand the risks of infection and potential risks and benefits of vaccination based on the health belief model[12 13], we used respondents' numeracy defined as the number of correct answers to the three questions used in a previous study[45]: *(1) If the chance of getting a disease is 10%, how many people out of 1,000 would be expected to get the disease?;* (2) *If 5 people all have the winning number in the lottery and the prize is 2 million dollars, how much will each of them get?; (3) Let's say you have 200 dollars in a savings account. The account earns 10% interest per year. How much would you have in the account at the end of two years?*

Empirical strategy

To assess the determinants of vaccine hesitancy, reasons for hesitating vaccination, and efficacies of the relaxation of public health restrictions on vaccine acceptance, we conducted the following three analyses.

(1) Determinants of vaccine hesitancy

We evaluated the association between vaccine hesitancy and its determinants, including demographic, socioeconomic, health, and psychological/behavioural factors. In the base model, we analysed the association using a logit model with a dichotomised outcome (i.e. unwilling to be vaccinated or undecided vs. willing to be vaccinated or already vaccinated). To test the robustness of the results, we assessed the association using a three-level nominal outcome (unwilling to be vaccinated vs. undecided vs. willing to be vaccinated or already vaccinated).

(2) Reasons for vaccine hesitancy

We investigated the determinants of the reasons for vaccine hesitancy by analysing the association between demographic, socioeconomic, health, and psychological/behavioural factors and each reason given by the individuals hesitating to be vaccinated. In our main analysis, we present results of our analysis on the determinants of vaccine hesitancy due to concerns about vaccine safety and side effects (i.e. concern about side effects and safety of the vaccine, plan to wait and see if it is safe and may get it later, or concern that the vaccine is being developed too quickly), and vaccine mistrust (i.e. dislike vaccines, the vaccine could give me COVID-19, or the vaccine will not work). We estimated the marginal effects of the factors for each reason using a logit model.

(3) Conjoint analysis: vaccine passport

To evaluate the association between the relaxation of public health restrictions by vaccine passports and vaccine acceptance, we utilised a conjoint experimental

design[18 46]. The conjoint experiment is useful in assessing the effects of varied attributes at different levels, with the reduced number of necessary assignments using an orthogonal table.

To develop conjoint tasks, we followed the ISPOR guideline[47]. Using this design, in a hypothetical situation, we asked each respondent whether they would be vaccinated, assuming that some or all public health restrictions are relaxed. While many types of attributes can affect vaccination intention, which were identified by our literature review, we focused on attributes about public health restrictions to reduce the burden of conjoint tasks by limiting the number of attributes and assigned tasks. Only with this, the respondents may implicitly assume that they are vaccinated by different types of vaccine; hence, we provided the information about the frequencies of side effects from the COVID-19 vaccine, which were obtained from the web site of the Ministry of Health, Labour, and Welfare[48].

To determine the attributes of public health restrictions included in our conjoint experiment, considering the public health policy relevance, we selected four attributes, which correspond to the government requests to the citizens to be compliant with: travelling across prefectures, dining out at night, joining gatherings and events, and going out without face masks. For each public health restriction, there are two attribute levels of being exempted from the restrictions or not exempted.

Without the design, we would need to assign 16 (= 2^4) questions to assess each attribute of vaccine passports to each respondent; however, we reduced assignments by half, as shown in Table 1. This process was done by generating an orthogonal and balanced design, assuming that each attribute was independent. As the number of tasks was within the acceptable range[47], we asked each respondent to complete all the eight tasks.

In the conjoint experiment, all respondents provided their vaccination intentions for each hypothetical vaccine passport. To account for potential non-random variance across respondents arising from repeated measures, we fitted population-average panel-data models using the method of generalised estimating equations[49], estimating robust standard errors, and considering logit models with binominal distributions of outcomes.

To assess potential heterogeneity across individual characteristics, we further conducted a sub-group analysis focusing on individuals aged 45 or younger, who were associated with higher probabilities of vaccine hesitancy in our analysis as discussed later.

Moreover, we conducted five additional analyses to check the robustness of our findings: a) analysis without the respondents whose choices may have been nontransitive; b) separate analysis for respondents who were undecided and unwilling to be vaccinated; c) analysis including respondents who intended to be vaccinated earlier or had already been vaccinated; d) analysis without those who provided a uniform answer to all options; e) analysis by a multilevel mixed-effects logistic regression to relax the assumption of the independence of irrelevant alternatives. Regarding the robustness test (a), we excluded the respondents whose choices may have been nontransitive. Some individuals preferred not to be vaccinated when an additional relaxation was offered, although they expressed their willingness to be vaccinated with fewer options. Although this may suggest that they did not prefer to ease certain restrictions regardless of vaccination status, we re-analysed the association by excluding them, assuming that their choices were irrational. For the robustness test (c), from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (that is, all yes or no), to

focus solely on individuals whose intention changed with vaccine passports.

Table 1. Conjoint experimental design

	Available relaxations of restrictions by vaccine passports				Vaccine intensions
	Travel across prefectures	Dining out after 8 p.m.	Joining gatherings and events	Going out without face masks	Yes / No
Pattern A	×	×	×	×	
Pattern B	×	×	○	○	
Pattern C	×	○	×	○	
Pattern D	×	○	○	×	
Pattern E	○	×	×	○	
Pattern F	○	×	○	×	
Pattern G	○	○	×	×	
Pattern H	○	○	○	○	

(4) Stated and revealed intention to vaccination

By comparing responses from both the first and second surveys, we present the data showing whether stated vaccination intention reflects revealed vaccination behaviour. With matched responses and behaviours, this would provide a partial validation for relying on a questionnaire about the vaccination intention, even though not on the actual vaccination status.

All analyses were conducted using Stata MP, version 17.0 (StataCorp LLC, College Station, United States of America).

Results

Descriptive statistics

Table 2 summarises the descriptive statistics of the sample. Out of a total of 5,000 respondents, approximately 30% hesitated to be vaccinated (i.e. unwilling to be vaccinated: 12.5% and undecided: 17.9%). Vaccination intentions and status can change over time due to various factors, such as infection situation and vaccine availability. At the time of the survey, approximately 38% of the Japanese population had at least one dose of the COVID-19 vaccine[5], health professionals and older adults being prioritised. The proportion of the vaccinated population was almost identical to that of our sample (36.6%), indicating that our sample reflects the Japanese context well.

Table 3 presents the reasons for vaccine hesitancy among the individuals who hesitate to vaccinate. The most major concerns were the vaccine's side effects and safety (87%), as well as other reasons related to vaccine safety, preference, and mistrust being commonly reported by respondents.

Table 2. Descriptive statistics (n = 5,000)

Variable	Mean or proportion	Standard deviation
Vaccine intentions: No	12.5%	
Undecided	17.9%	
Yes	33.1%	
Already vaccinated	36.6%	
Age	48.40	14.80
Female	50.3%	
Co-residence: Aged 65 or older	33.3%	
Aged 11 or younger	14.4%	
Chronic illness	25.0%	
Occupation: Healthcare worker	6.4%	
Frontline essential workers	26.3%	
Other occupations	31.8%	
Not employed (Ref.)	35.5%	
Education: High school or lower (Ref.)	31.2%	
Junior college or vocational	19.5%	
University or higher	49.2%	
Household income (million JPY)	5.60	3.78
Self-rated health	3.52	1.02
K10 depression scale	17.95	9.18
Numeracy	1.58	0.78
Time preference	21.08	16.21
Risk preference	27.85	8.3
Fear of COVID-19	19.63	5.46
Residential area: Hokkaido	4.6%	
Tohoku	5.9%	
Kanto	26.1%	
Chubu	14.9%	
Kinki	14.3%	
Chugoku	19.3%	
Shikoku	6.7%	
Kyushu	8.0%	

Table 3. Reasons for vaccine hesitancy

Reasons	%
Concern about side effects and safety of the vaccine	87%
Plan to wait and see if it is safe and may get it later	79%
Concern that the vaccine is being developed too quickly	73%
Plan to use masks/other precautions instead	69%
Do not trust the government	67%
Do not like vaccines	63%
Do not like needles	48%
Do not know I needed a vaccine against COVID-19	45%
The vaccine could give me COVID-19	37%
The vaccine will not work	31%
I will not need vaccinate because vaccination of other people will establish herd immunity	29%
Vaccination site is far	28%
COVID-19 is not a serious illness	26%
Too busy to visit a vaccination site	25%
Had COVID-19 and should be immune	11%
Doctor has not recommended a COVID-19 vaccine to me	11%
Pregnant	7%
For religious reasons	5%

Note: Percentages among 1,518 respondents hesitating vaccination.

Determinants of vaccine hesitancy

Table 4 shows the determinants of vaccine hesitancy. Compared to those aged 45–49, younger people aged 25–44 were likely to hesitate to get vaccinated, resulting in estimated odds ratios (ORs) ranging between 1.32 and 1.87, with 95% confidence intervals (CI) ranging from 1.01 to 2.44. Meanwhile, older adults aged 55–74 tended to accept vaccination, showing estimated ORs between 0.17 and 0.67 with 95% CI from 0.11 to 0.89. Female respondents tended to express vaccine hesitancy more than their male counterparts (OR: 1.18, 95% CI: 1.02 – 1.37). Additionally, those living with older adults and members with chronic illness tended to accept vaccination with higher probabilities compared to their counterparts not living with these population categories.

Socioeconomic factors are also associated with vaccine hesitancy. Healthcare workers, frontline essential workers, and those performing paid work were likely to be non-vaccine-hesitant compared to non-employed individuals: the former two groups were more likely to accept vaccination, showing ORs of 0.23 (95% CI: 0.16–0.33) and 0.71 (95% CI: 0.59–0.86), respectively. Furthermore, higher education and income were associated with a lower likelihood of being vaccine-hesitant.

Those with poorer health, measured by self-rated health and the K10 depression scale, were less likely to hesitate to get vaccinated with OR: 1.18 (95% CI: 0.76–0.89) and OR: 1.01 (95% CI: 1.00–1.02), respectively. Psychological and behavioural factors such as

time preference and fear of COVID-19 were also predictors of vaccine hesitancy.

When distinguishing those unwilling to get vaccinated and those who had not yet decided, similar results were observed for the findings estimated from the binary outcomes (Appendix Table A-1).

Table 4. Determinants of vaccine hesitancy

Vaccine hesitancy	Odds ratio	95%CI
Age (Ref. 45-49): 20-24	1.13	0.82 - 1.58
25-29	1.87**	1.44 - 2.44
30-34	1.67**	1.26 - 2.21
35-39	1.83**	1.42 - 2.36
40-44	1.32*	1.01 - 1.73
50-54	0.79	0.60 - 1.04
55-59	0.67**	0.50 - 0.89
60-64	0.40**	0.30 - 0.53
65-69	0.17**	0.11 - 0.26
70-74	0.18**	0.12 - 0.27
Female	1.18*	1.02 - 1.37
Co-residence: Aged 65 or older	0.84*	0.71 - 1.00
Aged 11 or younger	0.92	0.76 - 1.13
Chronic illness	0.56**	0.47 - 0.67
Occupation: Healthcare worker	0.23**	0.16 - 0.33
Frontline essential workers	0.71**	0.59 - 0.86
Other occupations	0.80*	0.67 - 0.95
Education: Junior college or vocational	0.85	0.70 - 1.03
University or higher	0.68**	0.58 - 0.80
Household income	0.95**	0.93 - 0.97
Self-rated health	0.82**	0.76 - 0.89
K10 depression scale	1.01**	1.00 - 1.02
Statistical literacy	0.96	0.87 - 1.05
Time preference	1.01**	1.00 - 1.01
Risk preference	1.00	0.99 - 1.01
Fear of COVID-19	0.97**	0.96 - 0.99
Constant	3.91**	2.07 - 7.42
Observations	5,000	

Note: Vaccine hesitancy refers to individuals who were undecided and unwilling to vaccinate; The outcome reference is 'Willing to vaccinate or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Reasons for vaccine hesitancy

In Figure 1 and 2, we present the results of the analyses on the reasons related to vaccine side effects and safety and mistrust, which were the most common. While we did not find remarkable heterogeneity across most factors, a higher numeracy was associated with vaccine hesitancy due to concerns about vaccine side effects and safety. Also, people aged 65 or older tended to show vaccine hesitancy due to both concerns about vaccine side effects or safety and mistrust. In contrast, vaccine hesitancy due to vaccine mistrust was less observed among younger people (i.e. individuals aged 25–29 and 30–34).

<Figure 1>

<Figure 2>

Additionally, the results for the determinants of vaccine hesitancy due to each reason are shown in Appendix Figures A-1, A-2, A-3, A-4, A-5, and A-6. Again, we did not find systematic trends in the determinants of the reasons for vaccine hesitancy.

Effectiveness of vaccine passport

From the conjoint experiment, we observed that 45% of all the vaccine-hesitant respondents intended to accept vaccination when all public health restrictions were relaxed, while 18% intended to do so if no restrictions were relaxed.

In Figure 3, we present the estimation results for the association between the

relaxation of each public health restrictions and vaccine acceptance, suggesting that relaxing all restrictions was effective in increasing vaccine acceptance by 4–10%. In particular, the relaxation of travel restriction across prefectures was the most effective, showing a 10% increase (95% CI: 9-11%) in vaccine acceptance, if permitted.

Moreover, we analysed the potential heterogeneity among younger people aged 44 or younger, who were more likely to be vaccine-hesitant in our previous analysis. We found that the results remained unchanged and these policies were particularly effective for younger people.

<Figure 3>

Additionally, we conducted the following five robustness tests. First, we excluded the respondents whose choices may have been nontransitive. However, the results remained unchanged (Appendix Figure A-7). Second, we separately analysed respondents who were undecided and unwilling to get vaccinated. Although marginal effects among those unwilling to get vaccinated became smaller while the estimation for undecided respondents became larger, we found that the relaxation of public health restrictions was evidently effective to increase vaccine acceptance (Appendix A-8). Third, we included respondents who intended to get vaccinated earlier or had already been vaccinated, and the same results were still observed (Appendix Figure A-9). Next, from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (i.e. all yes or no), the results

remained unchanged (Appendix Figure A-10). Finally, to relax the assumption of the independence of irrelevant alternatives, we estimated our main model by a multilevel mixed-effects logistic regression and confirmed the results were still robust (Appendix Figure A-11).

Stated and revealed vaccination intention

To check if participants' responses to the question about vaccination intention reflect their actual vaccination behaviour, for respondents who had not been vaccinated yet during the first survey, we present descriptive statistics on vaccination status at the follow-up survey (Table 5). More than 90% of respondents who intended to get vaccinated actually received it, while smaller proportions among those undecided and unwilling to be vaccinated did so afterwards. Approximately 29% of undecided and 69% of unwilling individuals remain vaccine-hesitant in the follow-up survey.

Table 5. Stated and revealed intention to vaccination

Wave1 \ Wave2	Vaccinated	Intend to vaccinate	Undecided	Unwilling to vaccinate	Total
Intend to vaccinate	94.9%	2.9%	1.3%	1.0%	1,424
Undecided	66.3%	4.5%	17.5%	11.8%	756
Unwilling to vaccinate	29.0%	1.3%	13.8%	55.9%	538
Total	73.9%	3.0%	8.2%	14.9%	2,718

Note: Wave1 was conducted between 21–23 July 2021, while Wave2 was held between 10-20 November 2021 as a follow-up survey of Wave1.

Discussion

During the time when citizens were imposed with public health restrictions due to the pandemic, this study primarily assessed whether easing public health restrictions by vaccine passports increases vaccine acceptance, especially among those with vaccine hesitancy, as well as investigated determinants of vaccine hesitancy and reasons for vaccine hesitancy. As the first study to explore the effectiveness of the relaxation of public health restrictions, by decomposing what can be permitted by vaccination, we obtained three main findings. First, in line with previous findings[3 8-11], our analysis suggests that demographic, socioeconomic, health-related, and psychological/behavioural factors predict vaccine hesitancy. In particular, younger age seems to be the strongest predictor of vaccine hesitancy, while other factors, such as gender and socioeconomic factors, were also associated with vaccine hesitancy. Second, concerns about the side effects and safety of the COVID-19 vaccine, as well as mistrust of vaccines and the government in general, were dominant reasons for vaccine hesitancy. Third, we found that vaccination acceptance increases by easing public health restrictions, especially travel restrictions across prefectures, at least when the citizens underwent public health restrictions. This result was particularly evident among younger people, who had higher probabilities of vaccine hesitancy than their older counterparts.

One reason why younger people tend to hesitate to be vaccinated is the expected balance between the costs and benefits of vaccination, as predicted by the health belief

model and economic theory[7 13]. Considering that younger people are less likely to develop severe COVID-19 symptoms than older people[16], and given the higher likelihood of the side effects of the vaccine (for example, headache and fatigue) among them[17], they could decide not to be vaccinated from a utilitarian perspective. While we did not observe remarkable trends for the association between age and the reasons for hesitating to vaccinate, vaccine safety and side effects were the most common reasons, which has also been reported by other studies[36 37]. Moreover, we found that statistical numeracy predicts vaccine hesitancy due to the concerns about vaccine safety and side effects. This may suggest that, being related to prospect theory, statistical capacity is related to inconsistent preferences and overestimating health losses of vaccination[50].

Our study also suggests that vaccine passports, which allow citizens freedom in their daily lives, could increase vaccine acceptance when they are imposed with public health restrictions due to the COVID-19 pandemic. Our finding is in line with the existing evidence that the freedom allowed by vaccine passports has positive impacts on vaccine acceptance[29]. In many countries, including Japan, individuals are subject to containment and closure policies by governments to curb the spread of the virus, which requires them to avoid non-essential activities, such as eating out, travelling, and mass gatherings. As stay-at-home orders and social distancing behaviours can deteriorate citizens' well-being and mental health through distress, boredom, loneliness, and social isolation[51], eliminating public health

restrictions and returning to a normal life may be what many citizens are eager to attain. Particularly for younger people whose health benefits of vaccination could be less than that of older people, more freedom in their daily lives allowed by vaccine passports may be more attractive than mere health benefits obtained through vaccination.

Based on our findings, several policy implications can be drawn. First, information campaigns to convey accurate messages are extremely important to enhance the understanding of vaccination and remove avoidable vaccine mistrust. Utilising behavioural insights, better designs on how to best communicate with people to enhance vaccine uptake should be considered[23 24]. Second, emphasising benefits other than health (e.g. the relaxation of public health restrictions), if applicable, may enhance vaccine acceptance, when the citizens are imposed with the restrictions.

Even under the concerns about breakthrough infections, the overall public health benefits may be in surplus if and only if a rise in vaccine acceptance largely reduces severe symptoms and the mortality rate from infection given the confirmed safety of the vaccine by contributing to the establishment of herd immunity against COVID-19. The continuous evaluations and careful consideration of the efficacy, duration of effectiveness, and side effects of the vaccine, as well as potential public health impact and ethical issues of vaccine passports are indispensable. With the uncertain duration of vaccine efficacy and the efficacy against new virus variants, it would be realistic to issue vaccine passports for a limited time,

maintaining moderate infectious control measures.

Furthermore, these types of passports must not be used to discriminate and eliminate the unvaccinated from society, allowing them to use alternative services, such as a certificate for a negative COVID-19 test result. Requiring these types of passports to re-engage in social activities may essentially violate the freedom of choice[31], which could be why some studies suggest that this type of scheme was viewed as negative[33 34]. Given the potential health risks of vaccination, it may not be feasible to mandate vaccination. In Japan, there is no vaccine mandate, not only for COVID-19 but for other diseases, while some of these are determined by law as non-binding obligations of the citizens. At least in the Japan's context, personal decision making for COVID-19 vaccination should reflect respect of their autonomy, with appropriate strategies to enhance understanding of benefits and risks about the vaccine and its attractiveness.

In this study, we first provided evidence on the effectiveness of vaccine passports to relax the public health restrictions, decomposing the activities allowed by passports, on reducing vaccine hesitancy in the context that the citizens were imposed with public health restrictions. Nevertheless, several limitations should be noted due to caveats. First, our study was based on a hypothetical experiment and not a real situation. Therefore, actual behaviour may diverge from the survey responses. Notwithstanding this limitation, our findings should still be helpful, based on previous reports that more than 80% of the stated and revealed

preferences corresponded [52] [53]. Also, in our study, a high proportion of the respondents provided consistent vaccination intentions and behaviours. Second, our findings are based on a survey, in which the sample was obtained from registered panels that may not be identical to the general public. Although we utilised weights estimated by population structures by region and vaccination rate/intention were similar to the official statistics and other surveys in Japan, other factors could not be representative. Also, vaccination intentions may fluctuate due to the pandemic situation and the timing of the survey. Furthermore, our results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy may vary across countries. In Japan, compared to Western countries, the COVID-19 mortality rate is much lower [54], and government responses to the pandemic are less stringent[55]; hence, the attitude of the Japanese population toward the vaccine and vaccine passports availability may differ from other countries. Therefore, intertemporal and cross-national evidence needs to be accumulated through further studies.

Conclusions

This study offers encouraging findings regarding the vaccination intentions of the Japanese people. Some individuals hesitate to get vaccinated against COVID-19 as the safety and side effects of the vaccine are a major concern; therefore, interventions to mitigate

these concerns through appropriate and effective information campaigns may help reduce vaccine hesitancy. Additionally, the relaxation of public health restrictions, such as travel across prefectures, wearing face masks, and dining out at night, is effective in enhancing vaccine acceptance when citizens undergo these restrictions. To assist the progress toward herd immunity, the feasibility of vaccine passports needs to be sufficiently assessed by taking the ethical issues of the passports and public health impacts of the relaxation of restrictions into careful consideration.

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a. Contributorship statement

Okamoto, Kamimura, and Komamura conceptualised the study and were engaged in the data collection. Okamoto and Kamimura conducted analyses, which were further refined and finalised by Okamoto. Komamura also provided critical comments to refine the analyses. Okamoto prepared a first draft, which was reviewed by Kamimura and Komamura.

b. Competing interests

The authors declare no conflicts of interest associated with this study.

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d. Data sharing statement: The data underlying this article cannot be shared publicly to maintain the anonymity of the study participants. The authors did not obtain consent from respondents to make the data open to the public. The full questionnaire used for the study is available from https://github.com/sokamoto-github/COVID-19-vaccine-hesitancy-and-vaccine-passports.

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Figure legends

Figure 1. Determinants of reasons for vaccine hesitancy: Demographic and socioeconomic factors

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

Figure 2. Determinants of reasons for vaccine hesitancy: Health-related and psychological/behavioural factors

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

Figure 3. Effectiveness of vaccine passport

Note: Estimates among individuals who were undecided and unwilling to vaccinate (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

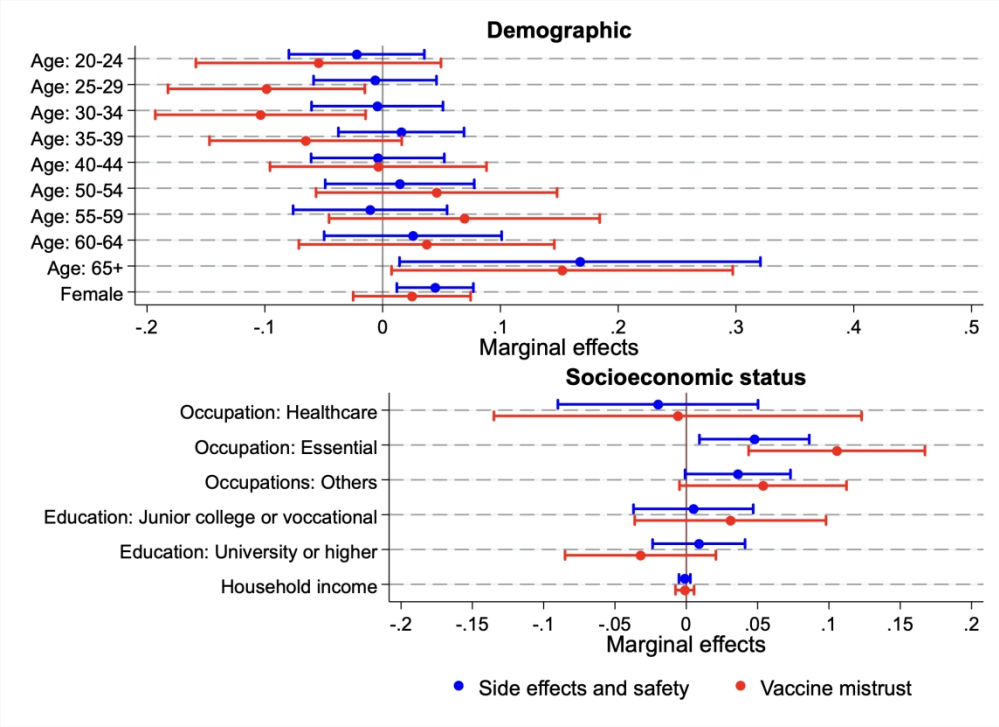

Figure 1. Determinants of reasons for vaccine hesitancy: Demographic and socioeconomic factors

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

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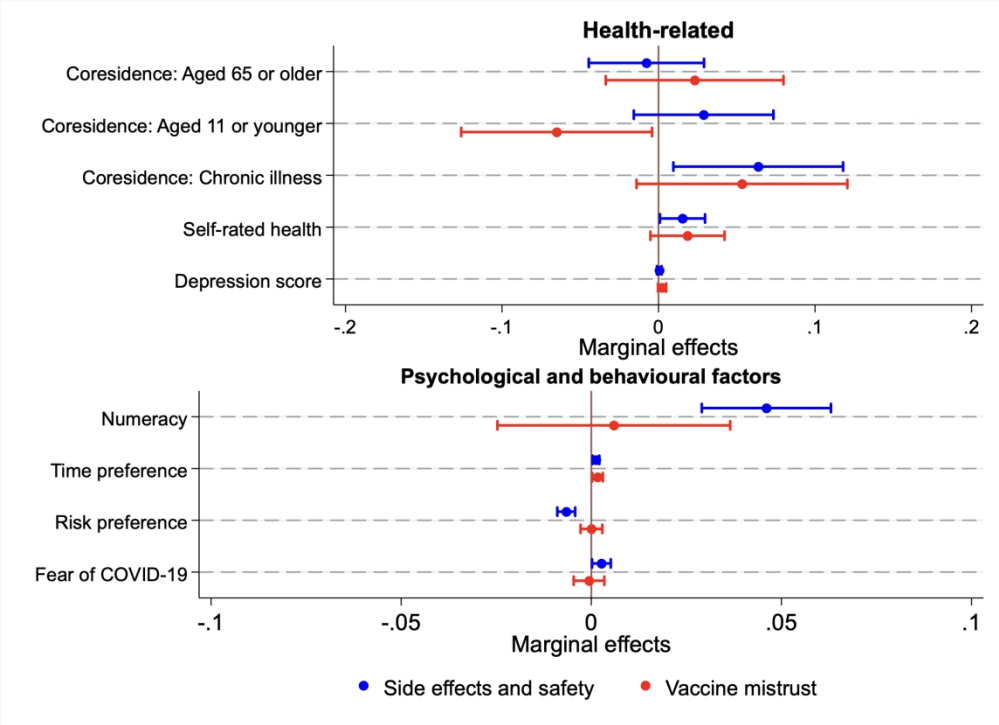

Figure 2. Determinants of reasons for vaccine hesitancy: Health-related and psychological/behavioural factors

Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

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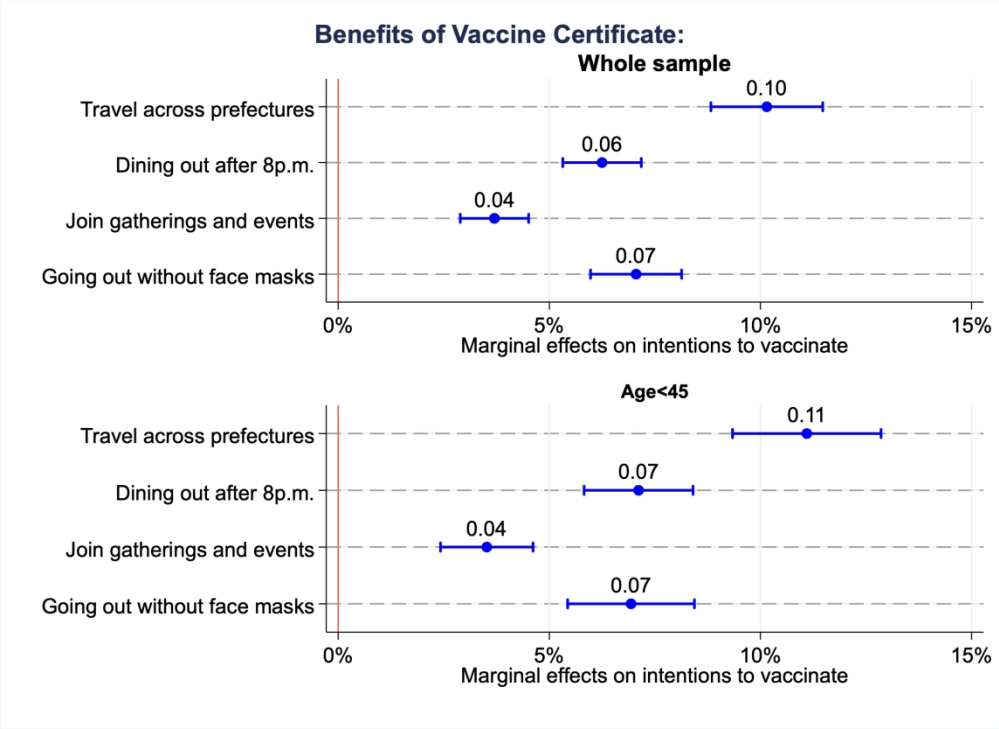

Figure 3. Effectiveness of vaccine passport

Note: Estimates among individuals who were undecided and unwilling to vaccinate (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

395x287mm (144 x 144 DPI)

Supplementary Material for
COVID-19 vaccine hesitancy and vaccine passports: A conjoint experiment in Japan

Shohei Okamoto[*1, 2, 3], Kazuki Kamimura[3, 4], Kohei Komamura[3, 5]

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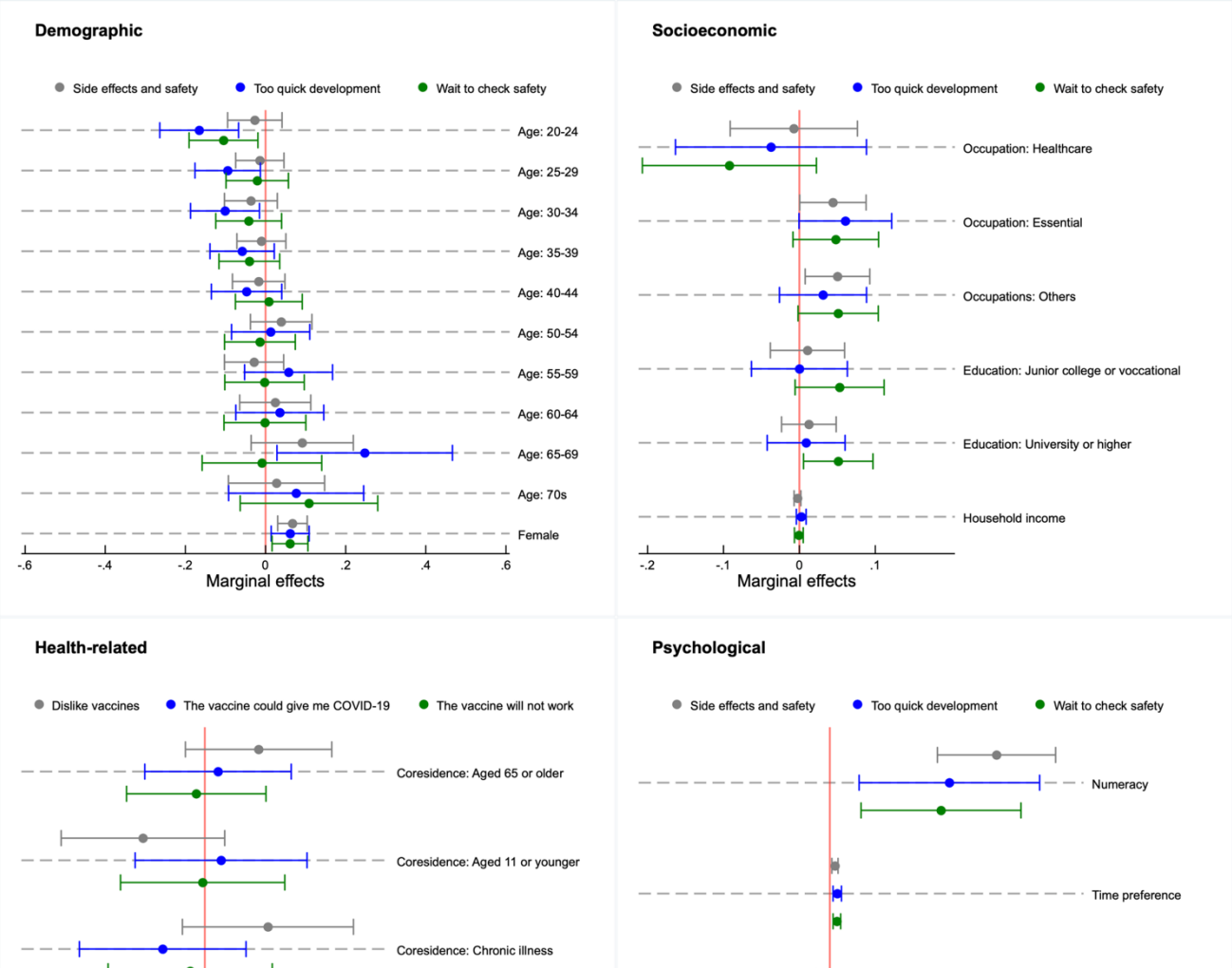
Contents

Appendix Table A-1. Determinants of vaccine hesitancy

	Will not vaccinate		Undecided	
Vaccine hesitancy	Relative risk ratios	95%CI	Relative risk ratios	95%CI
Age (Ref. 45-49): 20-24	1.48	0.95 - 2.30	0.94	0.63 - 1.41
25-29	1.97**	1.36 - 2.85	1.83**	1.35 - 2.47
30-34	2.08**	1.40 - 3.09	1.47*	1.07 - 2.03
35-39	2.22**	1.55 - 3.18	1.63**	1.22 - 2.19
40-44	1.46	0.99 - 2.15	1.25	0.92 - 1.70
50-54	0.87	0.58 - 1.29	0.75	0.55 - 1.04
55-59	0.89	0.59 - 1.35	0.55**	0.38 - 0.78
60-64	0.53**	0.35 - 0.79	0.33**	0.23 - 0.47
65-69	0.24**	0.13 - 0.42	0.14**	0.08 - 0.23
70-74	0.30**	0.18 - 0.51	0.11**	0.07 - 0.20
Female	1.08	0.88 - 1.32	1.26**	1.06 - 1.51
Co-residence: Aged 65 or older	0.75*	0.60 - 0.95	0.91	0.74 - 1.11
Aged 11 or younger	0.68*	0.50 - 0.92	1.10	0.88 - 1.38
Chronic illness	0.53**	0.41 - 0.68	0.59**	0.47 - 0.73
Occupation: Healthcare worker	0.26**	0.16 - 0.43	0.20**	0.13 - 0.33
Other essential workers	0.56**	0.43 - 0.73	0.83	0.67 - 1.04
Other occupations	0.70**	0.55 - 0.89	0.88	0.71 - 1.09
Education: Junior college or vocational	0.82	0.63 - 1.07	0.87	0.69 - 1.10
University or higher	0.60**	0.48 - 0.75	0.74**	0.61 - 0.90
Household income	0.96*	0.94 - 0.99	0.94**	0.92 - 0.97
Self-rated health	0.79**	0.71 - 0.88	0.85**	0.78 - 0.92
K10 depression scale	1.01**	1.00 - 1.03	1.01	1.00 - 1.02
Statistical literacy	0.85**	0.75 - 0.96	1.05	0.94 - 1.17
Time preference	1.01*	1.00 - 1.01	1.01*	1.00 - 1.01
Risk preference	1.00	0.99 - 1.02	0.99	0.98 - 1.00
Fear of COVID-19	0.95**	0.93 - 0.97	0.99	0.98 - 1.01
Constant	3.01*	1.25 - 7.22	1.35	0.64 - 2.85
Observations	5,000			

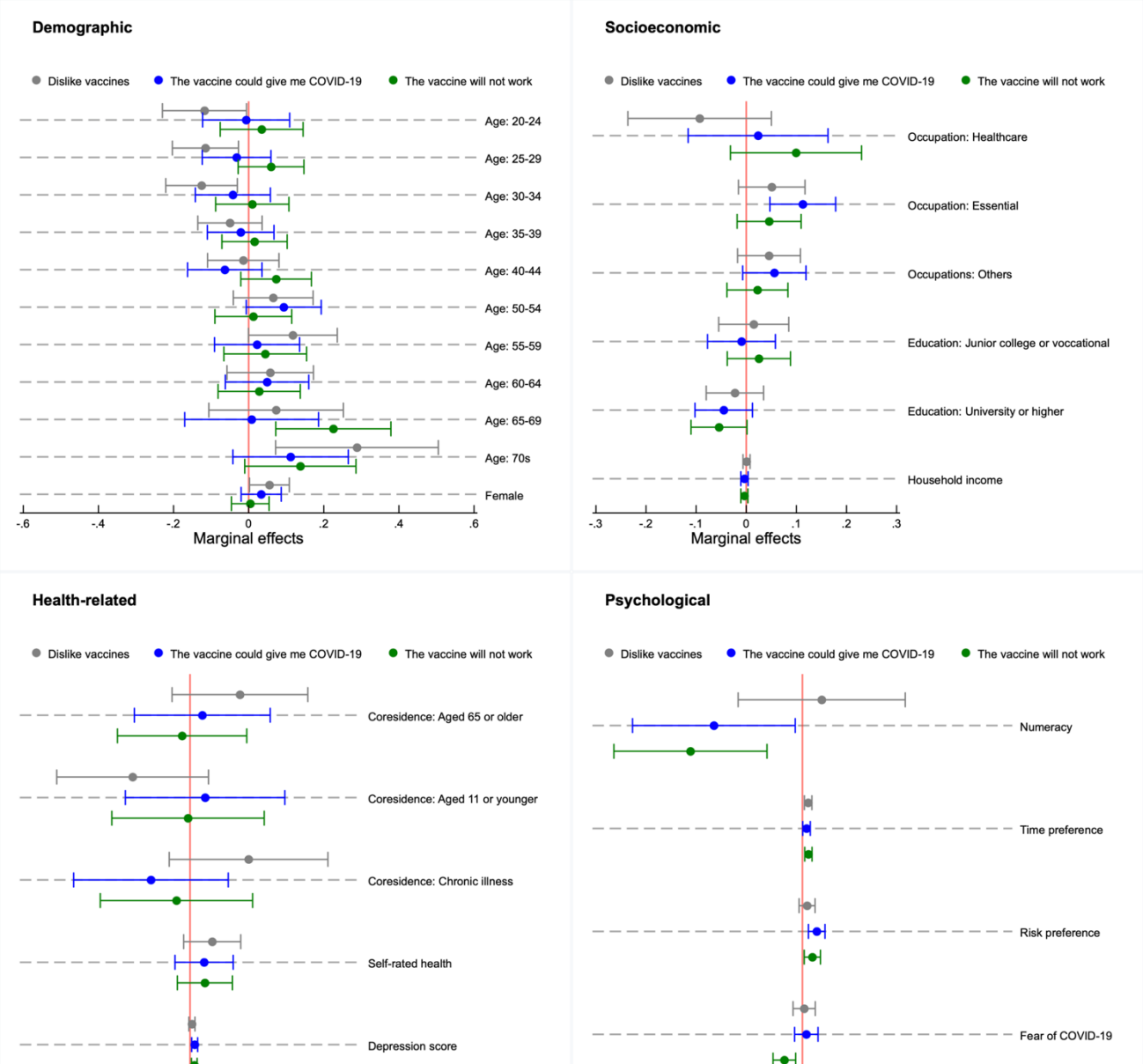
Note: The outcome reference is 'Willing to vaccinate or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Appendix Figure A-1. Determinants of reasons for vaccine hesitancy: Vaccine safety and side effects



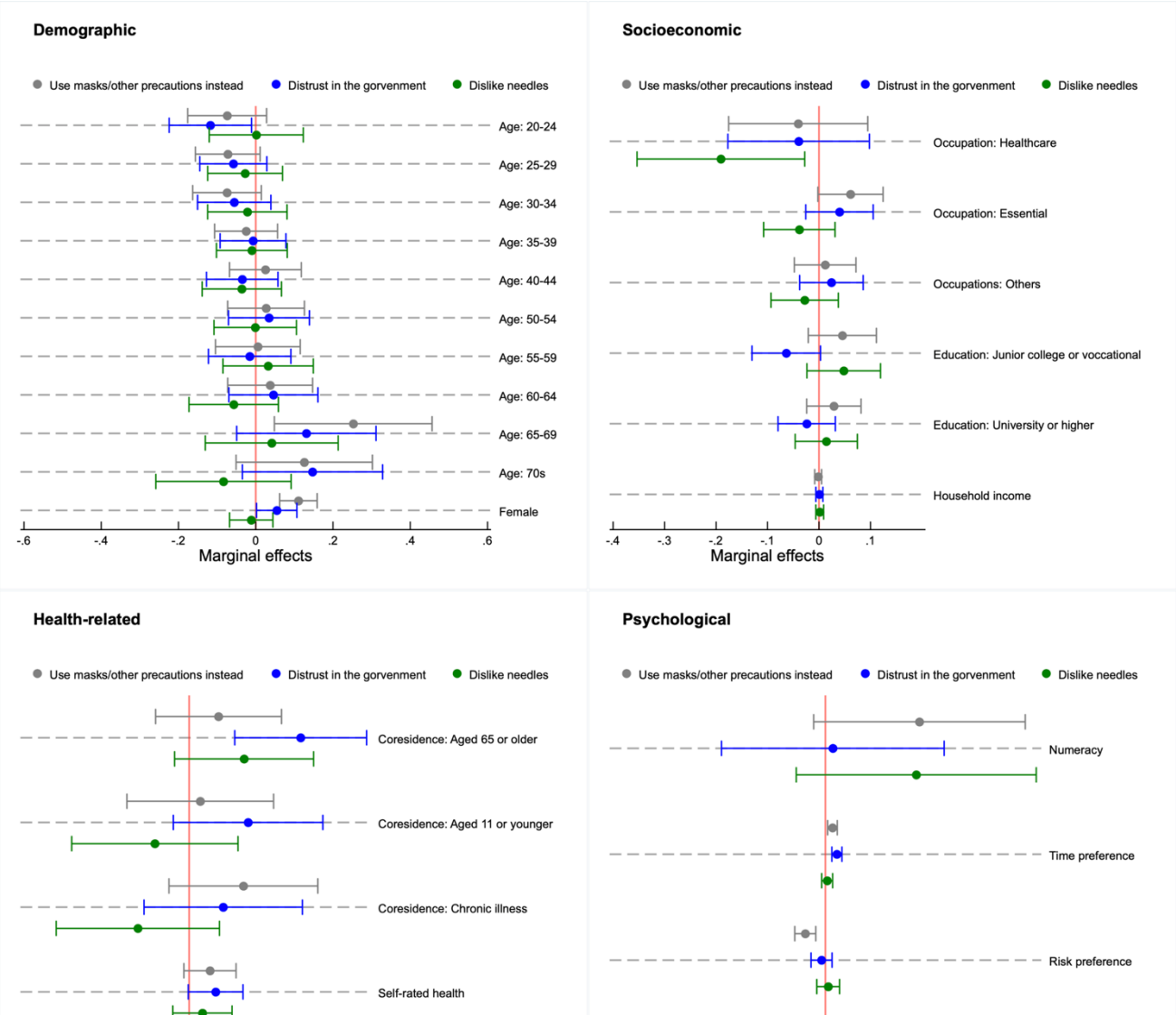
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-2. Determinants of reasons for vaccine hesitancy: Vaccine mistrust



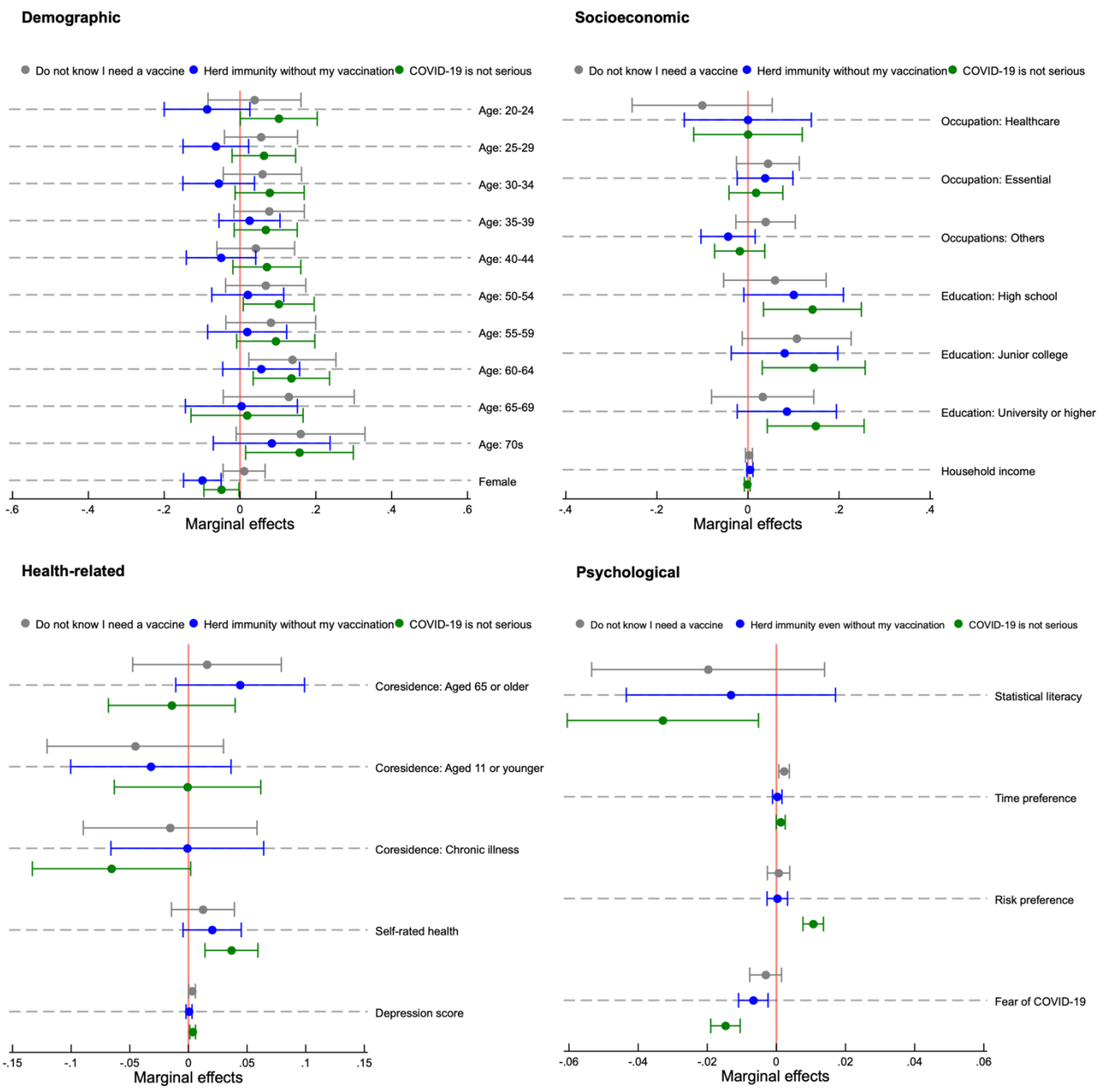
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-3. Determinants of reasons for vaccine hesitancy: Other mistrust



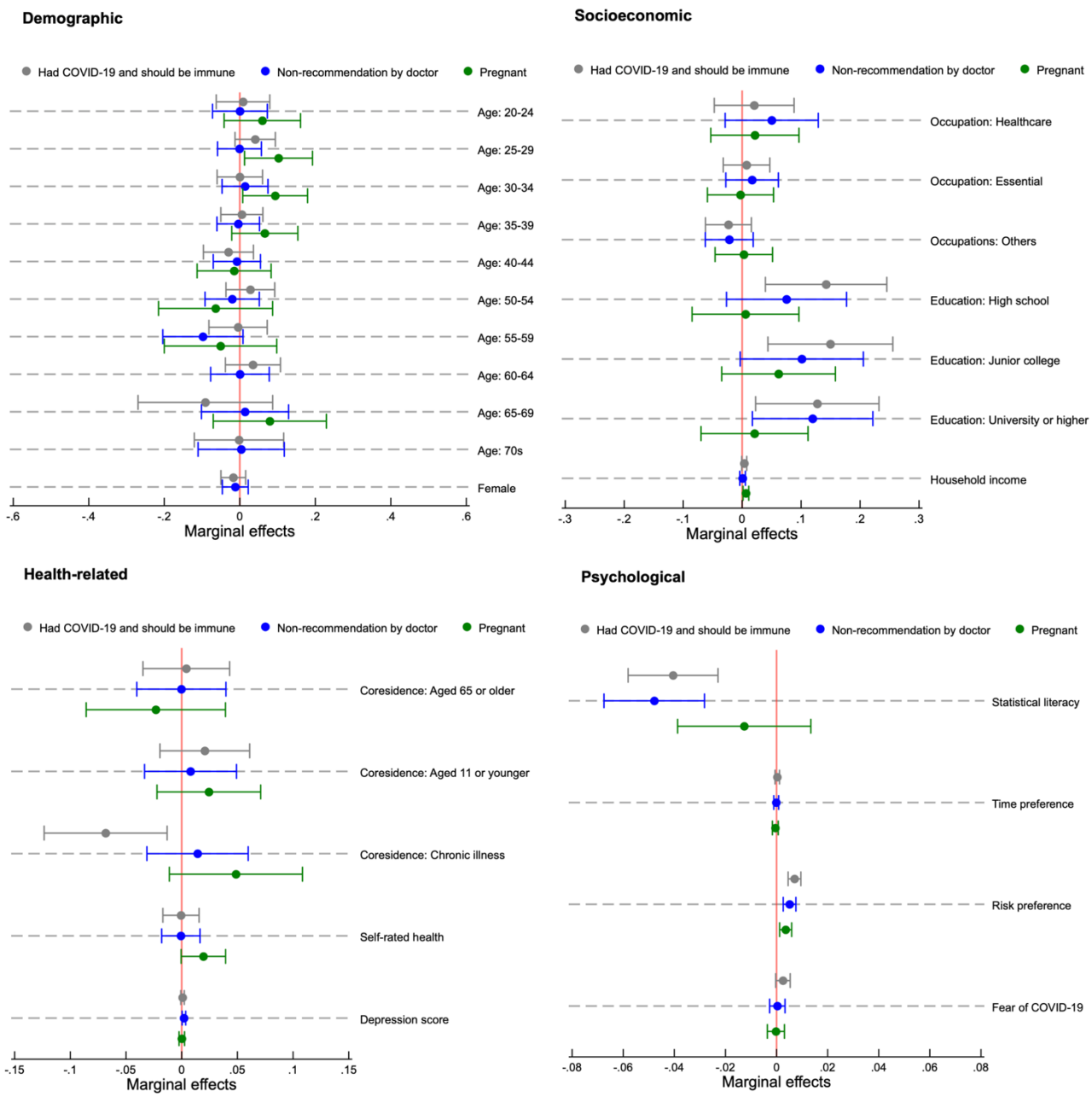
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-4. Determinants of reasons for vaccine hesitancy: Attitudes toward COVID-19



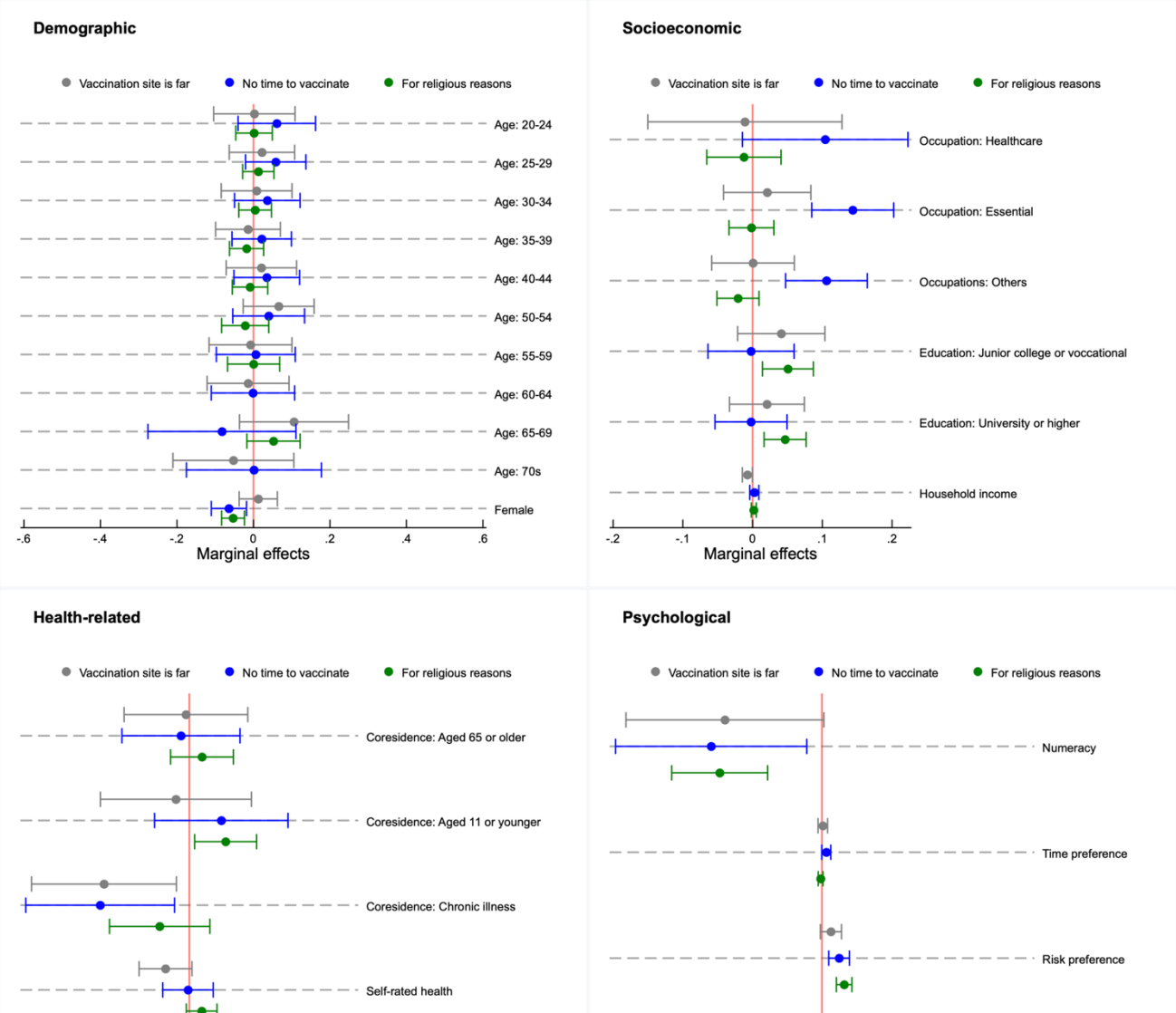
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-5. Determinants of reasons for vaccine hesitancy: Health-related reasons



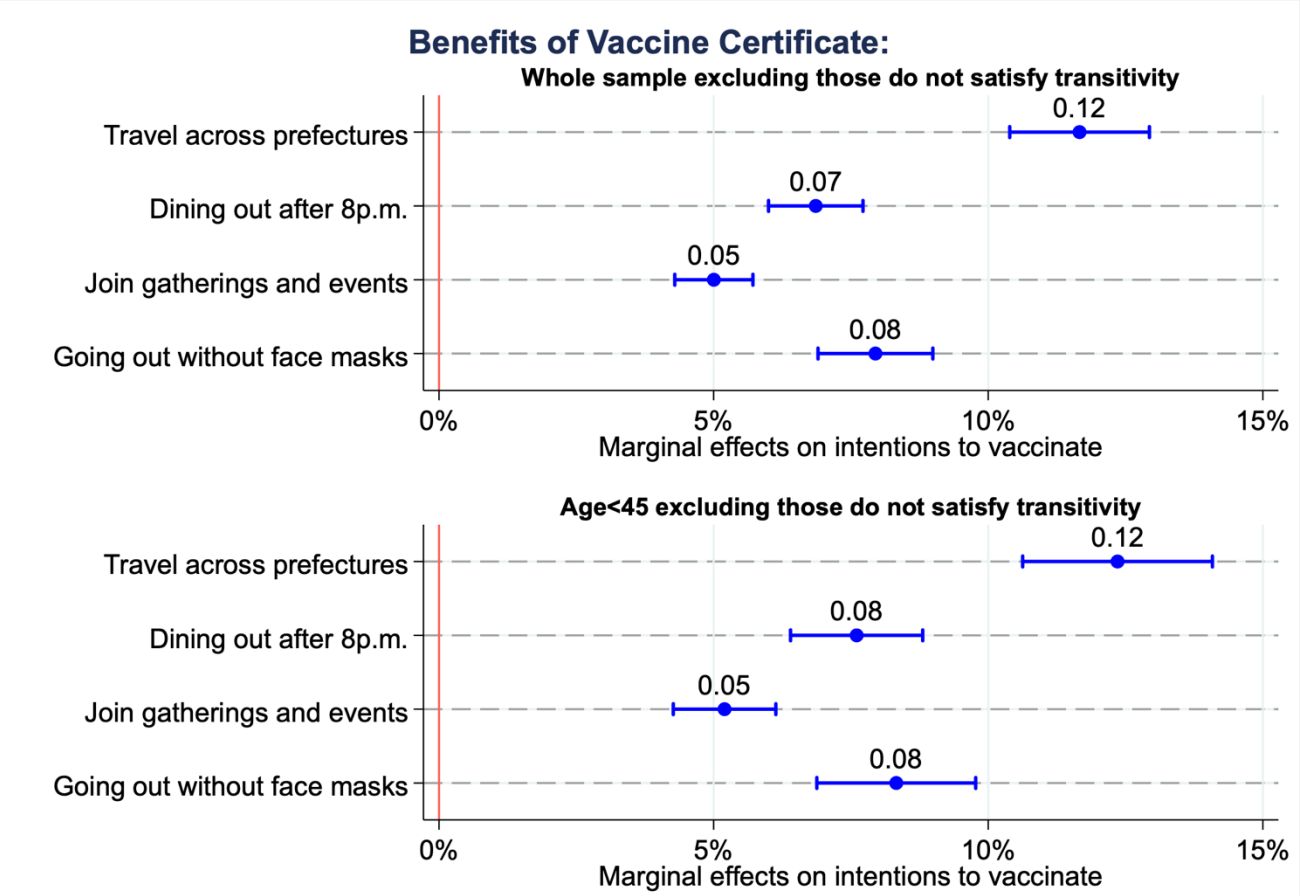
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-6. Determinants of reasons for vaccine hesitancy: Other reasons



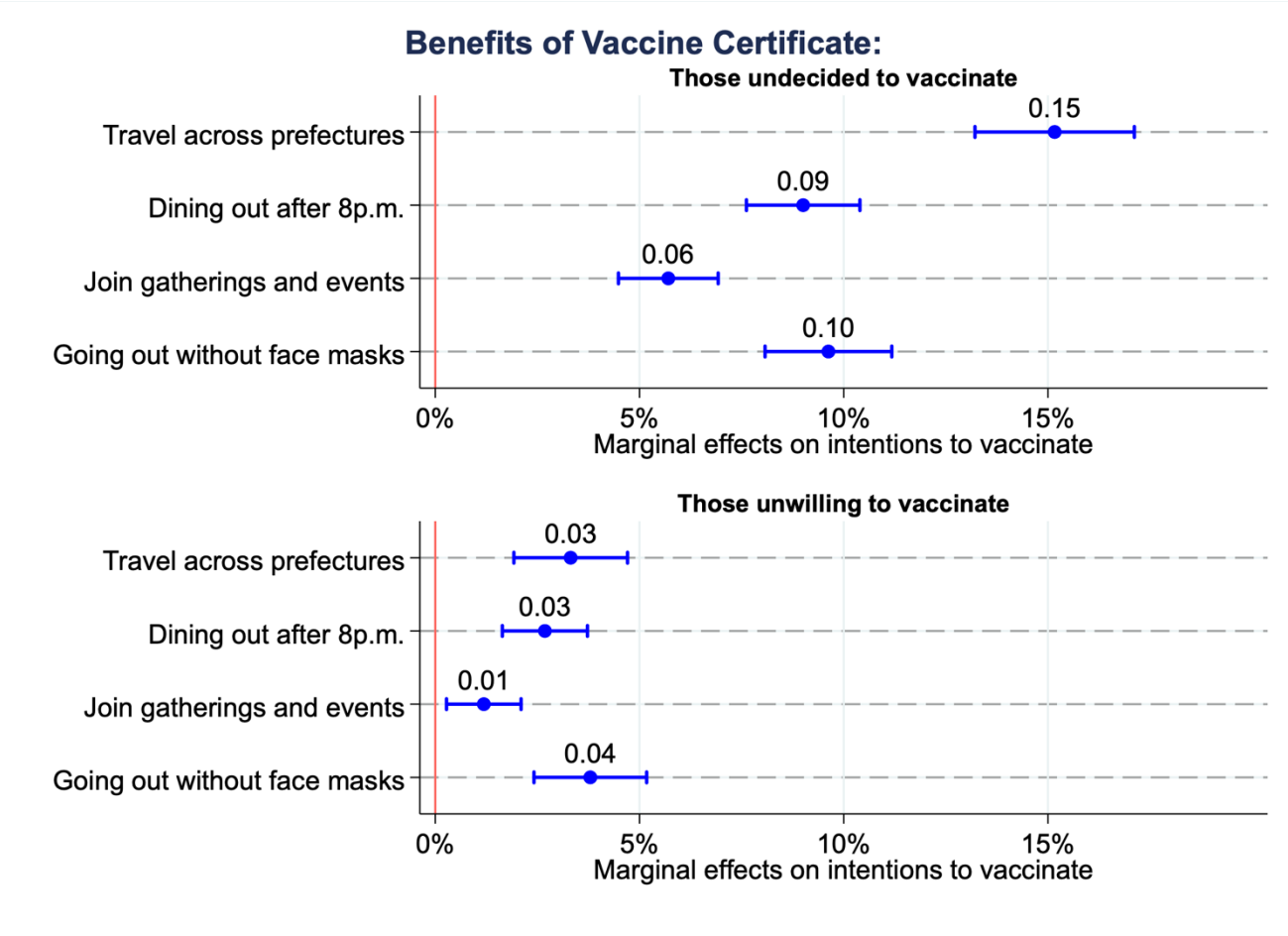
Note: Analyses among individuals who were undecided and unwilling to vaccinate (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-7. Vaccine passport: Exclude those with non-transitive preferences



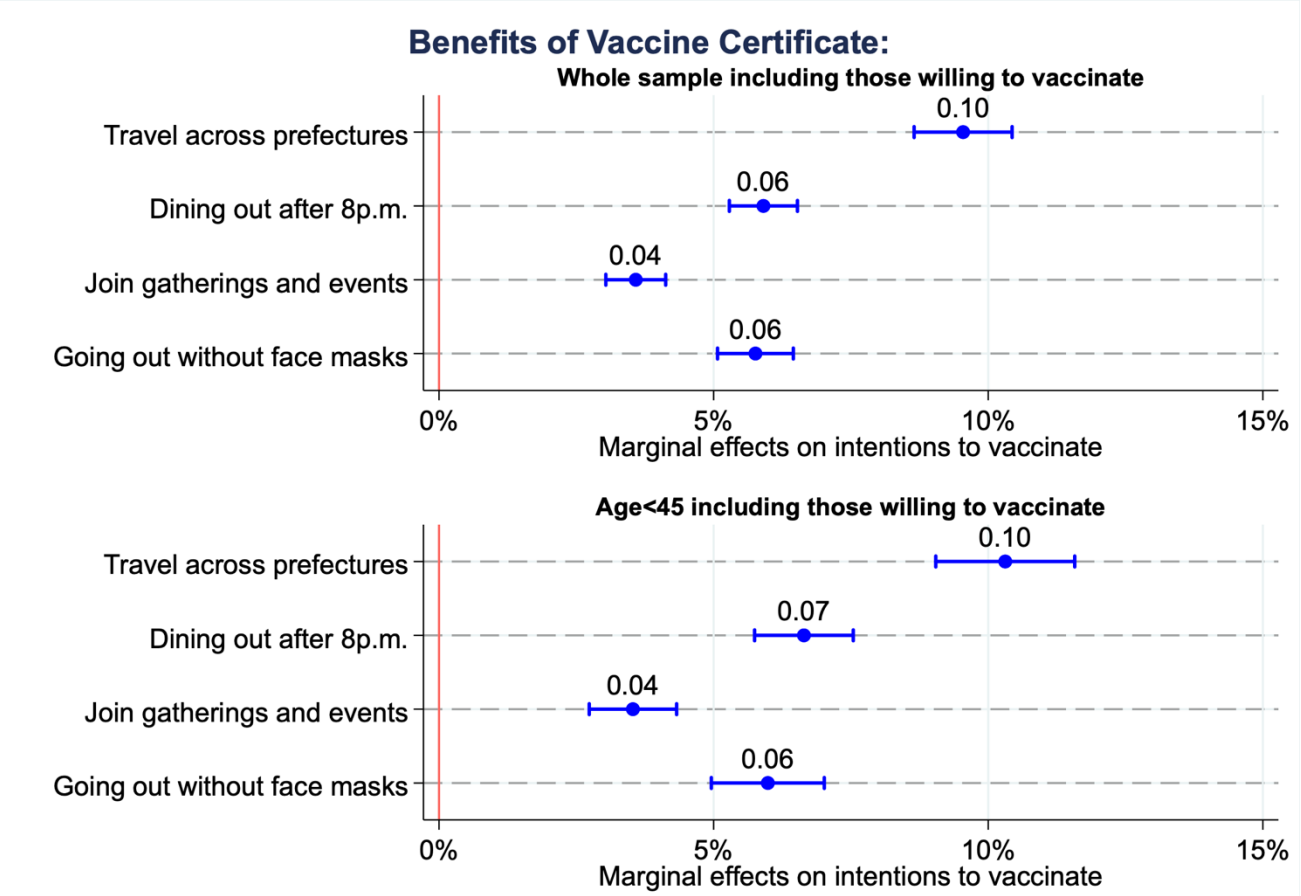
Note: Estimates among individuals who were undecided and unwilling to vaccinate, excluding those who did not satisfy transitivity of the vaccine preference (n= 1,416 for all age groups and n= 815 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

Appendix Figure A-8. Vaccine passport: Separate analyses of those undecided and unwilling to vaccinate



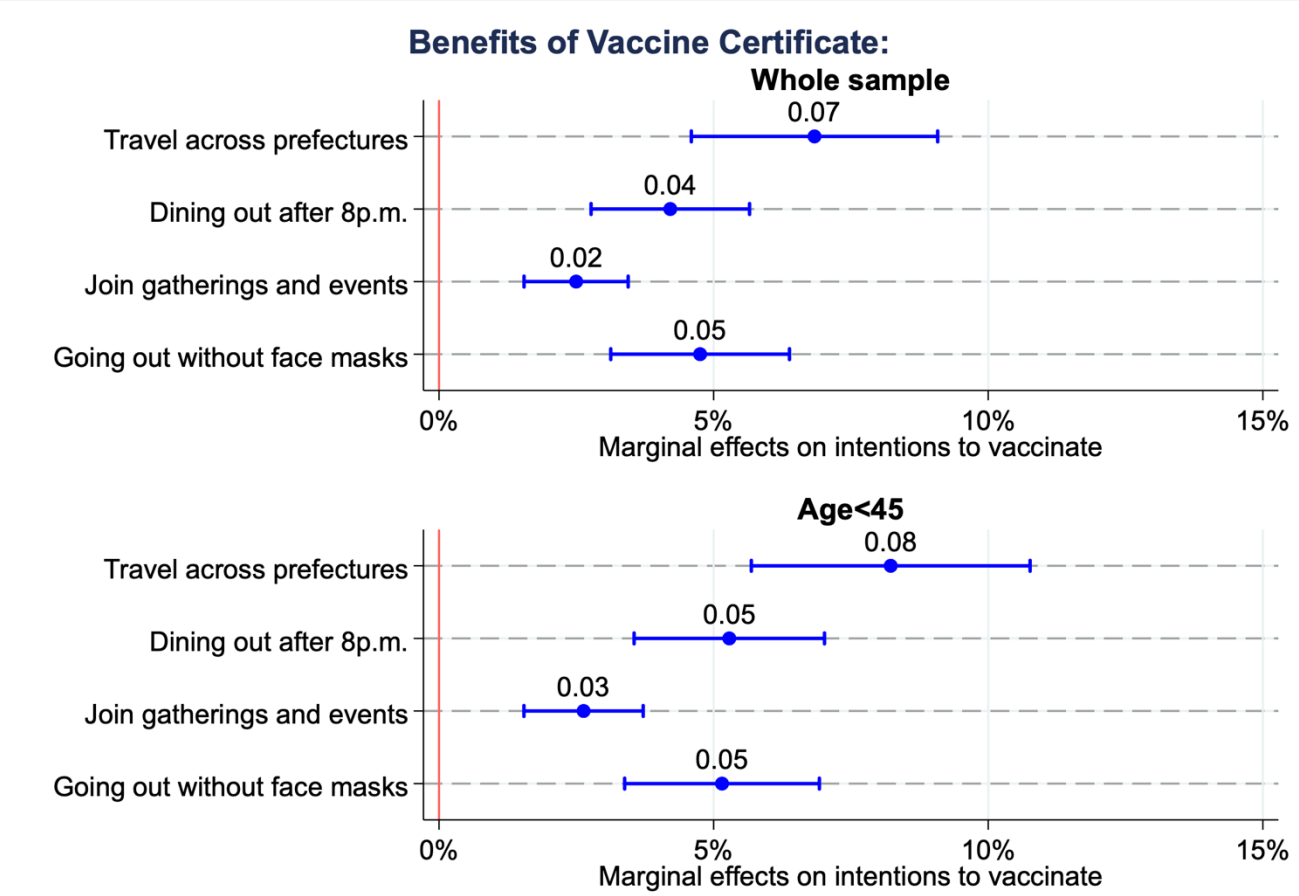
Note: Estimates among individuals who were unwilling to vaccinate (n= 894 for those undecided to vaccinate and n= 624 for those unwilling to vaccinate); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

Appendix Figure A-9. Vaccine passport: Include those willing to vaccinate



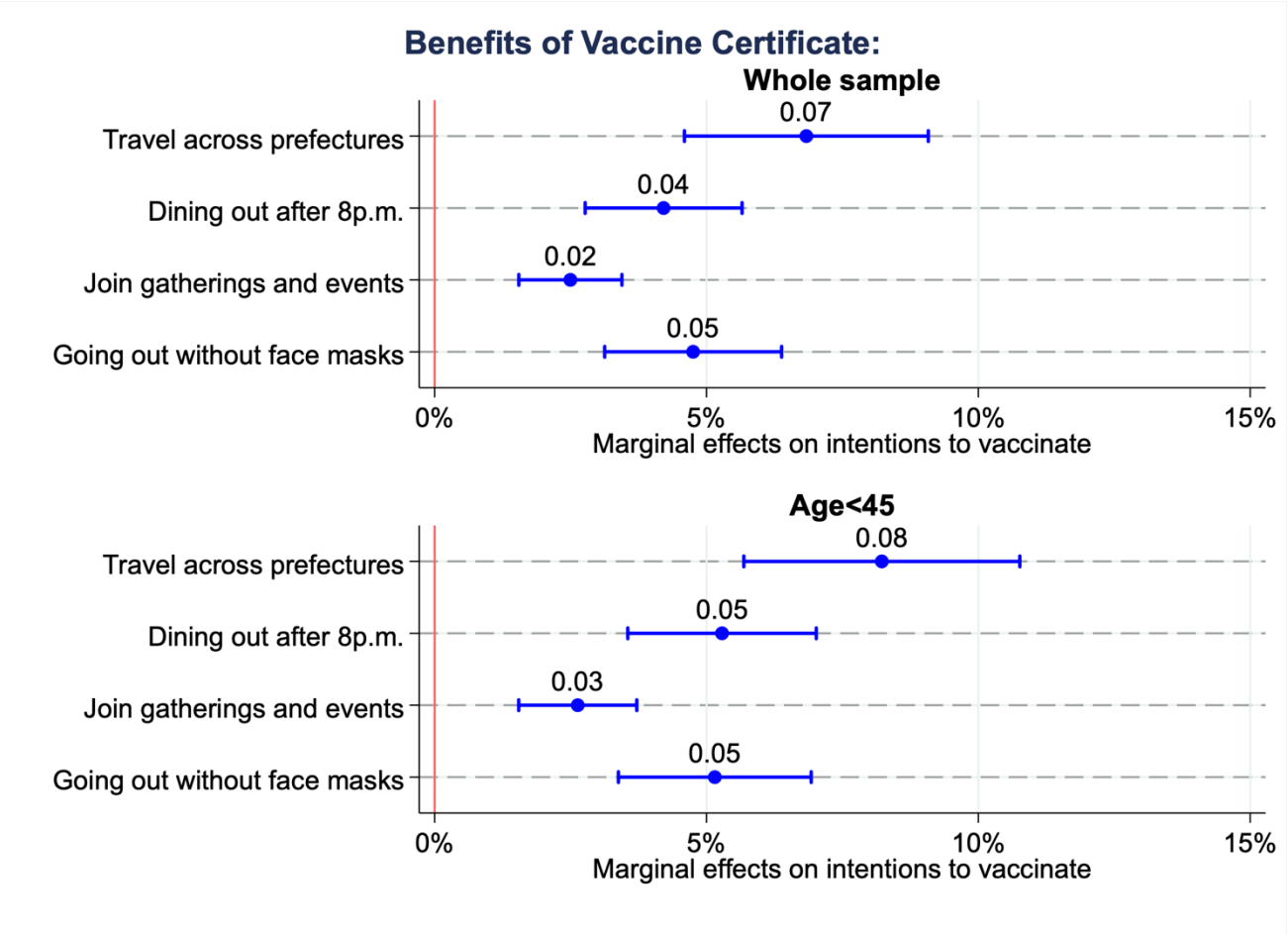
Note: Estimates among individuals who have not vaccinated yet, including 'Unwilling,' 'Undecided,' and 'Willing' (n= 3,171 for all age groups and n= 1,644 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

Appendix Figure A-10. Vaccine passport: Exclude uniform individuals



Note: Estimates among individuals who were undecided and unwilling to vaccinate, excluding those who provided uniform answers regarding their vaccination intentions regardless of available options (n= 1,531 for all age groups and n= 754 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

Appendix Figure A-11. Vaccine passport: Estimates by multilevel mixed-effects logistic regression



Note: Estimated by multilevel mixed-effects logistic regression with random intercepts by individuals among those who were undecided and unwilling to vaccinate (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to vaccinate; Full results are available upon request.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-9
Objectives	3	State specific objectives, including any prespecified hypotheses	9
Methods			
Study design	4	Present key elements of study design early in the paper	10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	10
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	11, 12
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*10-12*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-14
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13, 14
		(*b*) Describe any methods used to examine subgroups and interactions	13, 14
		(*c*) Explain how missing data were addressed	NA
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	10

	(e) Describe any sensitivity analyses	14-17

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*NA*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*NA*
		Cross-sectional study—Report numbers of outcome events or summary measures	*14*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-18
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	18-19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20, 21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

COVID-19 vaccine hesitancy and vaccine passports: A cross-sectional conjoint experiment in Japan

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Complete List of Authors:	Okamoto, Shohei; Tokyo Metropolitan Institute of Gerontology, Research team for social participation and community health; National Center for Global Health and Medicine, Institute for Global Health Policy Research Kamimura, Kazuki; Konan University, Hirao School of Management Komamura, Kohei; Keio University, Faculty of Economics
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Health economics, Health policy, Health services research, Infectious diseases, Immunology (including allergy)
Keywords:	COVID-19, HEALTH ECONOMICS, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Infection control < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

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COVID-19 vaccine hesitancy and vaccine passports: A cross-sectional conjoint experiment in Japan

Short title: COVID-19 vaccine hesitancy and vaccine passports

Shohei Okamoto[*1, 2, 3], Kazuki Kamimura[3, 4], Kohei Komamura[3, 5]

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Abstract

Objectives: While the development of vaccines against the novel coronavirus (COVID-19) brought hope of establishing herd immunity and ending the global pandemic, vaccine hesitancy can hinder the progress towards herd immunity. In this study, by analysing the data collected when citizens undergo public health restrictions due to the pandemic, we assess the determinants of vaccine hesitancy, reasons for hesitation, and potential effectiveness of vaccine passports used to relax public health restrictions on mitigating vaccine hesitancy.

Design: Cross-sectional study, longitudinal study, and conjoint experimental design.

Setting: An online survey conducted in Japan in July 2021

Participants: A demographically representative sample of 5,000 Japanese adults aged 20–74.

Primary outcome measures: COVID-19 vaccination intention

Results: We found that about 30% of respondents did not intend to get vaccinated or had not yet decided, with major reasons for vaccine hesitancy relating to concerns about the safety and side effects of the vaccine. In line with previous findings, younger age, lower socioeconomic status, and psychological and behavioural factors such as weaker COVID-19 fear were associated with vaccine hesitancy. Easing of public health restrictions such as travel, wearing face masks, and dining out at night was associated with an increase in vaccine acceptance by 4–10%. Moreover, we found that more than 90% of respondents who intended to get vaccinated actually received it while smaller proportions among those undecided and unwilling to get vaccinated did so.

Conclusion: With a major concern about vaccine safety and side effects, interventions to mitigate against these may help reduce vaccine hesitancy. Moreover, when citizens

are imposed with restrictions, vaccine passports that increase their freedom may be helpful to increase vaccination rates.

Strengths and limitations of this study

- This study includes timely data on COVID-19 vaccine hesitancy, obtained from a demographically representative sample of 5,000 Japanese adults.
- The data were collected in July 2021 when the citizens were imposed with public health restrictions.
- A conjoint experiment allows assessing the effectiveness of easing public health restrictions on vaccine acceptance.
- Actual behaviour may diverge from the survey responses or fluctuate due to the pandemic situation and the timing of the survey.
- Results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy can vary across countries.

Introduction

After a period when nations have managed to curb the spread of the new coronavirus disease (COVID-19), mainly by non-pharmaceutical interventions such as containment and closure policies, the development of COVID-19 vaccines brought hope that the pandemic may end soon. Although the degree and duration of vaccine efficacy as well as the efficacy against new virus variants remain unconfirmed, widespread vaccination can contribute to establishing herd immunity against COVID-19. While the required proportions of individuals with immunity could vary by country (e.g. due to demographic structure and frequency of human contact), it is estimated that approximately 70% of the population needs immunity to achieve herd immunity against COVID-19, which would require more than 30 million deaths worldwide due to natural infection[1]. Therefore, global vaccination is a necessary step to end the pandemic.

However, vaccine hesitancy, defined as a 'delay in acceptance or refusal of vaccines despite availability of vaccine services' by a working group advising the World Health Organization[2], can hinder achieving herd immunity. The findings of systematic reviews and meta-analyses suggest that the vaccine acceptance rates are approximately 60–75% but show large discrepancies across regions, months of studies, and whether an answer of 'unsure' is available to survey respondents[3 4]. Together with the global disparities in vaccine availability for COVID-19, full vaccination rates are considerably low, and only approximately a third of the world population had received at least one dose of a vaccine against COVID-19 by August 2021[5]. While this low vaccine uptake may be due to many reasons, including individual preferences and other factors, such as system failures, identifying why people are reluctant to be vaccinated is important.

Whether an individual accepts vaccination is a consequence of a complex decision-making process, which occurs on the continuum between complete acceptance and refusal[2]. The above-mentioned working group developed the 'three Cs vaccine hesitancy model', which comprises confidence, complacency, and convenience, indicating that historic, socio-cultural, environmental, health system/institutional, economic, or political factors, as well as personal perception and vaccine/vaccination characteristics influence vaccine hesitancy. Moreover, from a utilitarian perspective, voluntary vaccinations can deviate from the social optimum owing to the positive externalities of vaccinated individuals; hence, Pigouvian subsidies, external regulations, or strategies to improve vaccine awareness are needed, depending on the nature of vaccine-preventable diseases and vaccines[6 7].

Therefore, it is important to understand the reasons for COVID-19 vaccine hesitancy, in addition to strategies to raise the vaccination rates. In the following section, we review the literature on the determinants of COVID-19 vaccine hesitancy.

Literature on COVID-19 vaccine hesitancy

(1) Socio-demographic factors

Given the concerns of the increasing hesitancy towards COVID-19 vaccination, many empirical studies have hitherto assessed factors associated with COVID-19 vaccine hesitancy[3 8-11]. These studies suggest that many empirical papers find that older people compared to their younger counterparts and men compared to women are more likely to accept a COVID-19 vaccine. Older people are susceptible to the disease, and while men and women can decline vaccination for various reasons, the differences in perceived risks, efficacies, and knowledge may inform these gender differences[11]. In addition to age and gender, educational attainment is identified as the most frequent

predictor, with higher acceptance among people with higher education levels[3]. While highly educated individuals can be vaccine-hesitant because of the influence of social groups and other authorities, education may play an important role in understanding disease severity and vaccination benefits[11].

(2) Psychological and behavioural factors

Vaccination is a consequence of one's utility maximisation, considering costs and benefits. Based on the health belief model, by modifying socio-demographic factors, individuals can decide whether to be vaccinated as a reflection of their personal beliefs about a disease and its preventive measures, such as susceptibility, severity, benefits, barriers, and self-efficacy[12 13]. A systematic review identifies that vaccine acceptance is higher among those with greater perceived risk, threat, vulnerability, and susceptibility to infection[8 9]. Furthermore, the beliefs about the vaccine are predictors of vaccine hesitancy, including mistrust in its safety or efficacy and conspiracy beliefs, which can be induced by low health literacy and negative information in the media[8].

Together with one's perceptions regarding vaccines and infection, individual preferences matter for health-related decision-making, including vaccination[14 15]. Time preference affects one's vaccination intentions because individuals will benefit from the vaccination in the future, despite having to bear its present costs. Therefore, those discounting future benefits would lead them to decide not to be vaccinated. Moreover, the attitudes toward risks are attributed to vaccination decision-making, that is, risk-averse individuals would feel conflicted between the risk of infection without vaccination and the vaccines' side effects. This would explain why younger people tend to be vaccine-hesitant, considering they are less likely to develop symptoms than their older counterparts[16] and have more frequent side effects[17]. In addition to

individuals' attributes and beliefs, vaccine characteristics are important determinants of vaccination intention, being highly relevant to individuals' perceptions and preferences for vaccines. In particular, individuals prefer vaccines with higher efficacy, longer duration of disease protection, and safety (that is, none or few adverse effects)[8 18].

Vaccination campaigns

To increase vaccination rates, considering the determinants of vaccine hesitancy discussed above and vaccine characteristics, potential strategies would include removing the (mis)perceived effectiveness and risks of vaccination and infection, minimising the costs associated with vaccination (i.e. out-of-pocket payments and opportunity cost), and increasing the benefits of vaccination by providing various incentives. In fact, several approaches, such as communication, financial and non-financial incentives, and reminder-recall interventions, have been adopted and evaluated so far[19 20].

Vaccination campaign frameworks have also been adopted to increase COVID-19 vaccination uptake. Aiming at a better understanding of the population for COVID-19 vaccines, public organisations disseminate information about the efficacy and safety of vaccines[21 22]. Additionally, a study suggests that emphasising the benefits of vaccination and inducing feelings of vaccine ownership are useful[23 24], thus suggesting the importance of information campaigns. In some countries, the convenience of vaccination locations is enhanced by providing these services within the areas of citizens' daily lives, such as train stations and supermarkets[25 26]. Furthermore, the incentives towards vaccination attract the attention of some policymakers[27], although their effectiveness remains inconclusive and may depend on

how incentives are given[28 29].

With remaining ethical concerns, 'vaccine passports', which denote certifications of vaccinations to fully or partially exempt vaccinated individuals from public health restrictions[30 31], are considered in many regions. The core rationale of vaccine passports is that public health restrictions due to the pandemic should be tailored to respond to public demands for the relaxation of the restrictions, when the scheme would be safe for at least some individuals. Despite these relative merits of vaccine passports, this scheme may work negatively for some individuals as requiring certifications to re-engage in social activities can essentially be a violation of individual freedom of choice[31]. While only a limited number of related studies are available, the freedom allowed by vaccine passports can affect vaccine acceptance and preference both positively and negatively: A study found that more freedom allowed by vaccination can increase vaccination uptake[29 32]. In contrast, some studies suggest that people do not prefer vaccination used as permission to engage in social activities[33 34], and thereby vaccine passports could be viewed negatively among some socio-demographic groups[32]. Despite the concern about `breakthrough infections', it would be worth considering the applicability of vaccine passports if and only if the passports largely contribute to achieving herd immunity against COVID-19 by increasing vaccine acceptance.

Literature gaps and aims of this study

Previous studies have documented the determinants of vaccine hesitancy by analysing the association of socio-demographic, psychological, and vaccine characteristics with vaccine intentions. Meanwhile, the evidence on how to increase COVID-19 vaccine acceptance remains scarce. In alignment with the policies in

several regions, the evidence on communication strategies and the incentives for reducing vaccine hesitancy have gained increasing attention, as discussed above, while the effectiveness of vaccine passports in raising vaccine acceptance has been limited. While countries such as Israel, France, and Italy attempt to utilise vaccine passports, other countries may also consider similar schemes to return to a 'normal life'. If so, it is immensely important to accelerate herd immunity by reducing avoidable vaccine hesitancy, to which the benefits of the vaccine passports may contribute. However, whether vaccine passports can contribute to increasing vaccination uptake is debatable.

Therefore, by analysing the data obtained when the citizens were exposed to public health restrictions, we assessed the effectiveness of easing public health restrictions by vaccine passports based on our analysis of a conjoint experiment. By decomposing the freedom factors allowed by the passport based on government regulations, we first evaluate an effective type of relaxation of public health restrictions to increase vaccine acceptance, which would be useful for health policymakers to design vaccine passports and curate compelling information on the benefits of vaccination for vaccine-hesitant individuals.

Methods

Data

The data come from a demographically representative sample of 5,000 Japanese adults aged 20–74 from an online survey conducted from 21–23 July 2021. In a non-experimental study setting that analyses the data by logistic regression, a previous study suggests that taking a minimum sample size of 500 is necessary to obtain reliable parameter estimates[35]: The sample size that we initially planned to collect was

well above this number, and thereby sufficient to obtain reliable estimates from an unbiased population. Survey respondents were recruited from registered panels of Cross Marketing Inc. To ensure that the survey is nationally representative regarding respondents' age and gender, we recruited respondents using quota sampling for each of the 14 age groups of the 2015 population census (that is, age categories of 20s, 30s, 40s, 50s, 60s, and early 70s by gender).

While we did not use regional quotas to recruit respondents, we addressed the potential non-representativeness arising from this by using weights for all analyses and estimated by population structures in each region. Specifically, we used eight categories for residential areas (i.e. Hokkaido, Tohoku, and Kanto except for the Tokyo Metropolitan Area, Tokyo Metropolitan Area, Chubu, Kinki, Chugoku, Shikoku, and Kyusyu) and eleven categories for each five-year age group from 20 to 74. The pandemic situation during the study period varied across regions, with most per-day COVID-19 new cases confirmed in Tokyo, Kanto (for example, Saitama and Kanagawa), Kinki (for example, Osaka), and Kyushu (for example, Okinawa).

About four months after this survey (i.e. between 10th and 20th of November 2021), we conducted a follow-up survey of the same respondents to compare their vaccination intention and status during the first and second waves, respectively. We obtained 4,367 responses out of 5,000 participants in the first wave (87.3%).

COVID-19 situation in Japan

During the survey, approximately 5,000 COVID-19 cases were reported per day as the number kept increasing. The state of emergency or quasi-state of emergency was declared in Tokyo, Okinawa, Saitama, Chiba, Kanagawa, and Osaka. In these areas, individuals and business owners were requested to refrain from engaging in non-

essential activities. In addition to the citizens in these prefectures, all the citizens in Japan were requested by the government to take preventive measures from the infection, such as wearing a face mask, hand washing, avoiding 'Three Cs' (i.e. closed spaces, crowded places, and close-contact settings), and ensuring adequate ventilation.

Ethical approval

This study was approved by the Institutional Review Board of the Institute of Economics Studies, Keio University (No. 21009R and 21011R). We obtained informed consent from the participants by providing information about the study and asking them to participate only if they understood the survey and agreed to join before answering the questionnaire.

Patient and Public Involvement statement

There was no patient and public involvement in this study.

Definitions of variables

(1) Vaccine-related questions

To measure vaccine hesitancy, we asked respondents their vaccination intentions, based on response options: already vaccinated, willing to be vaccinated, undecided, and unwilling to be vaccinated. Following the definition of vaccine hesitancy[2], we operationally defined those who were undecided and unwilling to vaccinate as vaccine-hesitant.

In instances where respondents hesitated to be vaccinated, we additionally asked them about the reasons for rejecting a vaccine and the importance of those

reasons. Referring to previous investigations[36 37], we identified 18 items, such as concerns about the vaccine's side effects, safety, efficacy, and other reasons.

(2) Independent variables

To account for the factors associated with vaccine hesitancy, as indicated by previous findings[3 8-11], we obtained demographic, socioeconomic, health-related, and psychological information on each respondent.

The demographic and socioeconomic status of respondents included information on age, gender, co-resident family members, occupation, education, and income. Respondents living with members with chronic illnesses, aged 65 or over, and aged 11 or younger would be more likely to be vaccinated because they are considered vulnerable to infection or not eligible for COVID-19 vaccination in Japan. In terms of occupation, we used three categories; essential healthcare workers, frontline essential workers, and other workers, following existing definitions by the Centers for Disease Control and Prevention[38]. Specifically, frontline essential workers include those working in manufacturing, wholesale/retail, transportation/shipping/postal services, education, primary industry, and critical infrastructure (i.e. electricity, gas, heat supplying services, and waterworks), whose works must be performed on-site. Educational attainment of respondents included three categories—high school or lower, junior college or vocational school, and university or higher. Income refers to annual household income, obtained as the median value in 19 ranges.

We also used two health measures of self-rated health and depressive symptoms measured by the Kessler Psychological Distress Scale (K10), which have been validated by previous studies[39 40]. Higher scores indicate better health for the

former scale, whereas lower scores indicate worse health for the latter.

Finally, we used the following items, identified as predictors of one's preventive behaviours, to measure psychological and behavioural factors: to measure respondents' perceived seriousness of COVID-19, we used the Fear of COVID-19 Scale[41 42]. Time and risk preferences, which relate to individuals' responses to uncertain risks of vaccination and infection, were measured in the following two ways: the time preference was measured by a question, 'If you were to receive some funds in 13 months, instead of obtaining it in 1 month, how much is the lowest amount that would be adequate for your needs? [43]' The risk preference was obtained as the sum of the responses to seven questions on risk attitudes measured using a seven-point Likert scale[44], which indicates higher scores representing higher risk-taking.

To measure respondents' ability to understand the risks of infection and potential risks and benefits of vaccination based on the health belief model[12 13], we used respondents' numeracy defined as the number of correct answers to the three questions used in a previous study[45]: *(1) If the chance of getting a disease is 10%, how many people out of 1,000 would be expected to get the disease?;* (2) *If 5 people all have the winning number in the lottery and the prize is 2 million dollars, how much will each of them get?; (3) Let's say you have 200 dollars in a savings account. The account earns 10% interest per year. How much would you have in the account at the end of two years?*

Empirical strategy

To assess the determinants of vaccine hesitancy, reasons for hesitating vaccination, and efficacies of the relaxation of public health restrictions on vaccine acceptance, we conducted the following three analyses.

(1) Determinants of vaccine hesitancy

We evaluated the association between vaccine hesitancy and its determinants, including demographic, socioeconomic, health, and psychological/behavioural factors. In the base model, we analysed the association using a logit model with a dichotomised outcome (i.e. unwilling to be vaccinated or undecided vs. willing to be vaccinated or already vaccinated). To test the robustness of the results, we assessed the association using a three-level nominal outcome (unwilling to be vaccinated vs. undecided vs. willing to be vaccinated or already vaccinated).

(2) Reasons for vaccine hesitancy

We investigated the determinants of the reasons for vaccine hesitancy by analysing the association between demographic, socioeconomic, health, and psychological/behavioural factors and each reason given by the individuals hesitating to be vaccinated. In our main analysis, we present results of our analysis on the determinants of vaccine hesitancy due to concerns about vaccine safety and side effects (i.e. concern about side effects and safety of the vaccine, plan to wait and see if it is safe and may get it later, or concern that the vaccine is being developed too quickly), and vaccine mistrust (i.e. dislike vaccines, the vaccine could give me COVID-19, or the vaccine will not work). We estimated the marginal effects of the factors for each reason using a logit model.

(3) Conjoint analysis: vaccine passport

To evaluate the association between the relaxation of public health restrictions by vaccine passports and vaccine acceptance, we utilised a conjoint experimental

design[18 46]. The conjoint experiment is useful in assessing the effects of varied attributes at different levels, with the reduced number of necessary assignments using an orthogonal table.

To develop conjoint tasks, we followed the ISPOR guideline[47]. Using this design, in a hypothetical situation, we asked each respondent whether they would be vaccinated, assuming that some or all public health restrictions are relaxed. While many types of attributes can affect vaccination intention, which were identified by our literature review, we focused on attributes about public health restrictions to reduce the burden of conjoint tasks by limiting the number of attributes and assigned tasks. Only with this, the respondents may implicitly assume that they are vaccinated by different types of vaccine; hence, we provided the information about the frequencies of side effects from the COVID-19 vaccine, which were obtained from the web site of the Ministry of Health, Labour, and Welfare[48].

To determine the attributes of public health restrictions included in our conjoint experiment, considering the public health policy relevance, we selected four attributes, which correspond to the government requests to the citizens to be compliant with: travelling across prefectures, dining out at night, joining gatherings and events, and going out without face masks. For each public health restriction, there are two attribute levels of being exempted from the restrictions or not exempted.

Without the design, we would need to assign 16 (= 2^4) questions to assess each attribute of vaccine passports to each respondent; however, we reduced assignments by half, as shown in Table 1. This process was done by generating an orthogonal and balanced design, assuming that each attribute was independent. As the number of tasks was within the acceptable range[47], we asked each respondent to complete all the eight tasks.

In the conjoint experiment, all respondents provided their vaccination intentions for each hypothetical vaccine passport. To account for potential non-random variance across respondents arising from repeated measures, we fitted population-average panel-data models using the method of generalised estimating equations[49], estimating robust standard errors, and considering logit models with binominal distributions of outcomes.

To assess potential heterogeneity across individual characteristics, we further conducted a sub-group analysis focusing on individuals aged 45 or younger, who were associated with higher probabilities of vaccine hesitancy in our analysis as discussed later.

Moreover, we conducted five additional analyses to check the robustness of our findings: a) analysis without the respondents whose choices may have been nontransitive; b) separate analysis for respondents who were undecided and unwilling to be vaccinated; c) analysis including respondents who intended to be vaccinated earlier or had already been vaccinated; d) analysis without those who provided a uniform answer to all options; e) analysis by a multilevel mixed-effects logistic regression to relax the assumption of the independence of irrelevant alternatives. Regarding the robustness test (a), we excluded the respondents whose choices may have been nontransitive. Some individuals preferred not to be vaccinated when an additional relaxation was offered, although they expressed their willingness to be vaccinated with fewer options. Although this may suggest that they did not prefer to ease certain restrictions regardless of vaccination status, we re-analysed the association by excluding them, assuming that their choices were irrational. For the robustness test (c), from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (that is, all yes or no), to

focus solely on individuals whose intention changed with vaccine passports.

Table 1. Conjoint experimental design

	Available relaxations of restrictions by vaccine passports				Vaccine intensions
	Travel across prefectures	Dining out after 8 p.m.	Joining gatherings and events	Going out without face masks	Yes / No
Pattern A	×	×	×	×	
Pattern B	×	×	○	○	
Pattern C	×	○	×	○	
Pattern D	×	○	○	×	
Pattern E	○	×	×	○	
Pattern F	○	×	○	×	
Pattern G	○	○	×	×	
Pattern H	○	○	○	○	

(4) Stated and revealed intention to vaccination

By comparing responses from both the first and second surveys, we present the data showing whether stated vaccination intention reflects revealed vaccination behaviour. With matched responses and behaviours, this would provide a partial validation for relying on a questionnaire about the vaccination intention, even though not on the actual vaccination status.

All analyses were conducted using Stata MP, version 17.0 (StataCorp LLC, College Station, United States of America).

Results

Descriptive statistics

Table 2 summarises the descriptive statistics of the sample. Out of a total of 5,000 respondents, approximately 30% hesitated to be vaccinated (i.e. unwilling to be vaccinated: 12.5% and undecided: 17.9%). Vaccination intentions and status can change over time due to various factors, such as infection situation and vaccine availability. At the time of the survey, approximately 38% of the Japanese population had at least one dose of the COVID-19 vaccine[5], health professionals and older adults being prioritised. The proportion of the vaccinated population was almost identical to that of our sample (36.6%), indicating that our sample reflects the Japanese context well.

Table 3 presents the reasons for vaccine hesitancy among the individuals who hesitate to get vaccinated. The most major concerns were the vaccine's side effects and safety (87%), as well as other reasons related to vaccine safety, preference, and mistrust being commonly reported by respondents.

Table 2. Descriptive statistics (n = 5,000)

Variable	Mean or proportion	Standard deviation
Vaccine intentions: No	12.5%	
Undecided	17.9%	
Yes	33.1%	
Already vaccinated	36.6%	
Age	48.40	14.80
Female	50.3%	
Co-residence: Aged 65 or older	33.3%	
Aged 11 or younger	14.4%	
Chronic illness	25.0%	
Occupation: Healthcare worker	6.4%	
Frontline essential workers	26.3%	
Other occupations	31.8%	
Not employed (Ref.)	35.5%	
Education: High school or lower (Ref.)	31.2%	
Junior college or vocational	19.5%	
University or higher	49.2%	
Household income (million JPY)	5.60	3.78
Self-rated health	3.52	1.02
K10 depression scale	17.95	9.18
Numeracy	1.58	0.78
Time preference	21.08	16.21
Risk preference	27.85	8.3
Fear of COVID-19	19.63	5.46
Residential area: Hokkaido	4.6%	
Tohoku	5.9%	
Kanto	26.1%	
Chubu	14.9%	
Kinki	14.3%	
Chugoku	19.3%	
Shikoku	6.7%	
Kyushu	8.0%	

Table 3. Reasons for vaccine hesitancy

Reasons	%
Concern about side effects and safety of the vaccine	87%
Plan to wait and see if it is safe and may get it later	79%
Concern that the vaccine is being developed too quickly	73%
Plan to use masks/other precautions instead	69%
Do not trust the government	67%
Do not like vaccines	63%
Do not like needles	48%
Do not know I needed a vaccine against COVID-19	45%
The vaccine could give me COVID-19	37%
The vaccine will not work	31%
I will not need to get vaccinated because vaccination of other people will establish herd immunity	29%
Vaccination site is far	28%
COVID-19 is not a serious illness	26%
Too busy to visit a vaccination site	25%
Had COVID-19 and should be immune	11%
Doctor has not recommended a COVID-19 vaccine to me	11%
Pregnant	7%
For religious reasons	5%

Note: Percentages among 1,518 respondents hesitating vaccination.

Determinants of vaccine hesitancy

Table 4 shows the determinants of vaccine hesitancy. Compared to those aged 45–49, younger people aged 25–44 were likely to hesitate to get vaccinated, resulting in estimated odds ratios (ORs) ranging between 1.32 and 1.87, with 95% confidence intervals (CI) ranging from 1.01 to 2.44. Meanwhile, older adults aged 55–74 tended to accept vaccination, showing estimated ORs between 0.17 and 0.67 with 95% CI from 0.11 to 0.89. Female respondents tended to express vaccine hesitancy more than their male counterparts (OR: 1.18, 95% CI: 1.02 – 1.37). Additionally, those living with older adults and members with chronic illness tended to accept vaccination with higher probabilities compared to their counterparts not living with these population categories.

Socioeconomic factors are also associated with vaccine hesitancy. Healthcare workers, frontline essential workers, and those performing paid work were likely to be non-vaccine-hesitant compared to non-employed individuals: the former two groups were more likely to accept vaccination, showing ORs of 0.23 (95% CI: 0.16–0.33) and 0.71 (95% CI: 0.59–0.86), respectively. Furthermore, higher education and income were associated with a lower likelihood of being vaccine-hesitant.

Those with poorer health, measured by self-rated health and the K10 depression scale, were less likely to hesitate to get vaccinated with OR: 1.18 (95% CI: 0.76–0.89) and OR: 1.01 (95% CI: 1.00–1.02), respectively. Psychological and behavioural factors such as

time preference and fear of COVID-19 were also predictors of vaccine hesitancy.

When distinguishing those unwilling to get vaccinated and those who had not yet decided, similar results were observed for the findings estimated from the binary outcomes (Appendix Table A-1).

Table 4. Determinants of vaccine hesitancy

Vaccine hesitancy	Odds ratio	95%CI
Age (Ref. 45-49): 20-24	1.13	0.82 - 1.58
25-29	1.87**	1.44 - 2.44
30-34	1.67**	1.26 - 2.21
35-39	1.83**	1.42 - 2.36
40-44	1.32*	1.01 - 1.73
50-54	0.79	0.60 - 1.04
55-59	0.67**	0.50 - 0.89
60-64	0.40**	0.30 - 0.53
65-69	0.17**	0.11 - 0.26
70-74	0.18**	0.12 - 0.27
Female	1.18*	1.02 - 1.37
Co-residence: Aged 65 or older	0.84*	0.71 - 1.00
Aged 11 or younger	0.92	0.76 - 1.13
Chronic illness	0.56**	0.47 - 0.67
Occupation: Healthcare worker	0.23**	0.16 - 0.33
Frontline essential workers	0.71**	0.59 - 0.86
Other occupations	0.80*	0.67 - 0.95
Education: Junior college or vocational	0.85	0.70 - 1.03
University or higher	0.68**	0.58 - 0.80
Household income	0.95**	0.93 - 0.97
Self-rated health	0.82**	0.76 - 0.89
K10 depression scale	1.01**	1.00 - 1.02
Statistical literacy	0.96	0.87 - 1.05
Time preference	1.01**	1.00 - 1.01
Risk preference	1.00	0.99 - 1.01
Fear of COVID-19	0.97**	0.96 - 0.99
Constant	3.91**	2.07 - 7.42
Observations	5,000	

Note: Vaccine hesitancy refers to individuals who were undecided and unwilling to get vaccinated; The outcome reference is 'Willing to get vaccinated or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Reasons for vaccine hesitancy

In Figure 1 and 2, we present the results of the analyses on the reasons related to vaccine side effects and safety and mistrust, which were the most common. While we did not find remarkable heterogeneity across most factors, a higher numeracy was associated with vaccine hesitancy due to concerns about vaccine side effects and safety. Also, people aged 65 or older tended to show vaccine hesitancy due to both concerns about vaccine side effects or safety and mistrust. In contrast, vaccine hesitancy due to vaccine mistrust was less observed among younger people (i.e. individuals aged 25–29 and 30–34).

<Figure 1>

<Figure 2>

Additionally, the results for the determinants of vaccine hesitancy due to each reason are shown in Appendix Figures A-1, A-2, A-3, A-4, A-5, and A-6. Again, we did not find systematic trends in the determinants of the reasons for vaccine hesitancy.

Effectiveness of vaccine passport

From the conjoint experiment, we observed that 45% of all the vaccine-hesitant respondents intended to accept vaccination when all public health restrictions were relaxed, while 18% intended to do so if no restrictions were relaxed.

In Figure 3, we present the estimation results for the association between the

relaxation of each public health restrictions and vaccine acceptance, suggesting that relaxing all restrictions was effective in increasing vaccine acceptance by 4–10%. In particular, the relaxation of travel restriction across prefectures was the most effective, showing a 10% increase (95% CI: 9-11%) in vaccine acceptance, if permitted.

Moreover, we analysed the potential heterogeneity among younger people aged 44 or younger, who were more likely to be vaccine-hesitant in our previous analysis. We found that the results remained unchanged and these policies were particularly effective for younger people.

<Figure 3>

Additionally, we conducted the following five robustness tests. First, we excluded the respondents whose choices may have been nontransitive. However, the results remained unchanged (Appendix Figure A-7). Second, we separately analysed respondents who were undecided and unwilling to get vaccinated. Although marginal effects among those unwilling to get vaccinated became smaller while the estimation for undecided respondents became larger, we found that the relaxation of public health restrictions was evidently effective to increase vaccine acceptance (Appendix A-8). Third, we included respondents who intended to get vaccinated earlier or had already been vaccinated, and the same results were still observed (Appendix Figure A-9). Next, from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (i.e. all yes or no), the results

remained unchanged (Appendix Figure A-10). Finally, to relax the assumption of the independence of irrelevant alternatives, we estimated our main model by a multilevel mixed-effects logistic regression and confirmed the results were still robust (Appendix Figure A-11).

Stated and revealed vaccination intention

To check if participants' responses to the question about vaccination intention reflect their actual vaccination behaviour, for respondents who had not been vaccinated yet during the first survey, we present descriptive statistics on vaccination status at the follow-up survey (Table 5). More than 90% of respondents who intended to get vaccinated actually received it, while smaller proportions among those undecided and unwilling to be vaccinated did so afterwards. Approximately 29% of undecided and 69% of unwilling individuals remain vaccine-hesitant in the follow-up survey.

Table 5. Stated and revealed intention to vaccination

Wave1 \ Wave2	Vaccinated	Intend to get vaccinated	Undecided	Unwilling	Total
Intend to get vaccinated	94.9%	2.9%	1.3%	1.0%	1,424
Undecided	66.3%	4.5%	17.5%	11.8%	756
Unwilling	29.0%	1.3%	13.8%	55.9%	538
Total	73.9%	3.0%	8.2%	14.9%	2,718

Note: Wave1 was conducted between 21–23 July 2021, while Wave2 was held between 10-20 November 2021 as a follow-up survey of Wave1.

Discussion

During the time when citizens were imposed with public health restrictions due to the pandemic, this study primarily assessed whether easing public health restrictions by vaccine passports increases vaccine acceptance, especially among those with vaccine hesitancy, as well as investigated determinants of vaccine hesitancy and reasons for vaccine hesitancy. As the first study to explore the effectiveness of the relaxation of public health restrictions, by decomposing what can be permitted by vaccination, we obtained three main findings. First, in line with previous findings[3 8-11], our analysis suggests that demographic, socioeconomic, health-related, and psychological/behavioural factors predict vaccine hesitancy. In particular, younger age seems to be the strongest predictor of vaccine hesitancy, while other factors, such as gender and socioeconomic factors, were also associated with vaccine hesitancy. Second, concerns about the side effects and safety of the COVID-19 vaccine, as well as mistrust of vaccines and the government in general, were dominant reasons for vaccine hesitancy. Third, we found that vaccination acceptance increases by easing public health restrictions, especially travel restrictions across prefectures, at least when the citizens underwent public health restrictions. This result was particularly evident among younger people, who had higher probabilities of vaccine hesitancy than their older counterparts.

One reason why younger people tend to hesitate to be vaccinated is the expected balance between the costs and benefits of vaccination, as predicted by the health belief

model and economic theory[7 13]. Considering that younger people are less likely to develop severe COVID-19 symptoms than older people[16], and given the higher likelihood of the side effects of the vaccine (for example, headache and fatigue) among them[17], they could decide not to be vaccinated from a utilitarian perspective. While we did not observe remarkable trends for the association between age and the reasons for hesitating to get vaccinated, vaccine safety and side effects were the most common reasons, which has also been reported by other studies[36 37]. Moreover, we found that statistical numeracy predicts vaccine hesitancy due to the concerns about vaccine safety and side effects. This may suggest that, being related to prospect theory, statistical capacity is related to inconsistent preferences and overestimating health losses of vaccination[50].

Our study also suggests that vaccine passports, which allow citizens freedom in their daily lives, could increase vaccine acceptance when they are imposed with public health restrictions due to the COVID-19 pandemic. Our finding is in line with the existing evidence that the freedom allowed by vaccine passports has positive impacts on vaccine acceptance[29]. In many countries, including Japan, individuals are subject to containment and closure policies by governments to curb the spread of the virus, which requires them to avoid non-essential activities, such as eating out, travelling, and mass gatherings. As stay-at-home orders and social distancing behaviours can deteriorate citizens' well-being and mental health through distress, boredom, loneliness, and social isolation[51], eliminating public health

restrictions and returning to a normal life may be what many citizens are eager to attain. Particularly for younger people whose health benefits of vaccination could be less than that of older people, more freedom in their daily lives allowed by vaccine passports may be more attractive than mere health benefits obtained through vaccination.

Based on our findings, several policy implications can be drawn. First, information campaigns to convey accurate messages are extremely important to enhance the understanding of vaccination and remove avoidable vaccine mistrust. Utilising behavioural insights, better designs on how to best communicate with people to enhance vaccine uptake should be considered[23 24]. Second, emphasising benefits other than health (e.g. the relaxation of public health restrictions), if applicable, may enhance vaccine acceptance, when the citizens are imposed with the restrictions.

Even under the concerns about breakthrough infections, the overall public health benefits may be in surplus if and only if a rise in vaccine acceptance largely reduces severe symptoms and the mortality rate from infection given the confirmed safety of the vaccine by contributing to the establishment of herd immunity against COVID-19. The continuous evaluations and careful consideration of the efficacy, duration of effectiveness, and side effects of the vaccine, as well as potential public health impact and ethical issues of vaccine passports are indispensable. With the uncertain duration of vaccine efficacy and the efficacy against new virus variants, it would be realistic to issue vaccine passports for a limited time,

maintaining moderate infectious control measures.

Furthermore, these types of passports must not be used to discriminate and eliminate the unvaccinated from society, allowing them to use alternative services, such as a certificate for a negative COVID-19 test result. Requiring these types of passports to re-engage in social activities may essentially violate the freedom of choice[31], which could be why some studies suggest that this type of scheme was viewed as negative[33 34]. Given the potential health risks of vaccination, it may not be feasible to mandate vaccination. In Japan, there is no vaccine mandate, not only for COVID-19 but for other diseases, while some of these are determined by law as non-binding obligations of the citizens. At least in the Japan's context, personal decision making for COVID-19 vaccination should reflect respect of their autonomy, with appropriate strategies to enhance understanding of benefits and risks about the vaccine and its attractiveness.

In this study, we first provided evidence on the effectiveness of vaccine passports to relax the public health restrictions, decomposing the activities allowed by passports, on reducing vaccine hesitancy in the context that the citizens were imposed with public health restrictions. Nevertheless, several limitations should be noted due to caveats. First, our study was based on a hypothetical experiment and not a real situation. Therefore, actual behaviour may diverge from the survey responses. Notwithstanding this limitation, our findings should still be helpful, based on previous reports that more than 80% of the stated and revealed

preferences corresponded [52] [53]. Also, in our study, a high proportion of the respondents provided consistent vaccination intentions and behaviours. Second, our findings are based on a survey, in which the sample was obtained from registered panels that may not be identical to the general public. Although we utilised weights estimated by population structures by region and vaccination rate/intention were similar to the official statistics and other surveys in Japan, other factors could not be representative. Also, vaccination intentions may fluctuate due to the pandemic situation and the timing of the survey. Furthermore, our results may not be applicable in other countries, since the pandemic situation, government responses to the pandemic, and reasons for vaccine hesitancy may vary across countries. In Japan, compared to Western countries, the COVID-19 mortality rate is much lower [54], and government responses to the pandemic are less stringent[55]; hence, the attitude of the Japanese population toward the vaccine and vaccine passports availability may differ from other countries. Therefore, intertemporal and cross-national evidence needs to be accumulated through further studies.

Conclusions

This study offers encouraging findings regarding the vaccination intentions of the Japanese people. Some individuals hesitate to get vaccinated against COVID-19 as the safety and side effects of the vaccine are a major concern; therefore, interventions to mitigate

these concerns through appropriate and effective information campaigns may help reduce vaccine hesitancy. Additionally, the relaxation of public health restrictions, such as travel across prefectures, wearing face masks, and dining out at night, is effective in enhancing vaccine acceptance, particularly when citizens undergo these restrictions. To assist the progress toward herd immunity, the feasibility of vaccine passports needs to be sufficiently assessed by taking the ethical issues of the passports and public health impacts of the relaxation of restrictions into careful consideration.

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a. Contributorship statement

Okamoto, Kamimura, and Komamura conceptualised the study and were engaged in the data collection. Okamoto and Kamimura conducted analyses, which were further refined and finalised by Okamoto. Komamura also provided critical comments to refine the analyses. Okamoto prepared a first draft, which was reviewed by Kamimura and Komamura.

b. Competing interests

The authors declare no conflicts of interest associated with this study.

c. Funding

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d. Data sharing statement: The data underlying this article cannot be shared publicly to maintain the anonymity of the study participants. The authors did not obtain consent from respondents to make the data open to the public. The full questionnaire used for the study is available from https://github.com/sokamoto-github/COVID-19-vaccine-hesitancy-and-vaccine-passports.

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Figure legends

Figure 1. Determinants of reasons for vaccine hesitancy: Demographic and socioeconomic factors

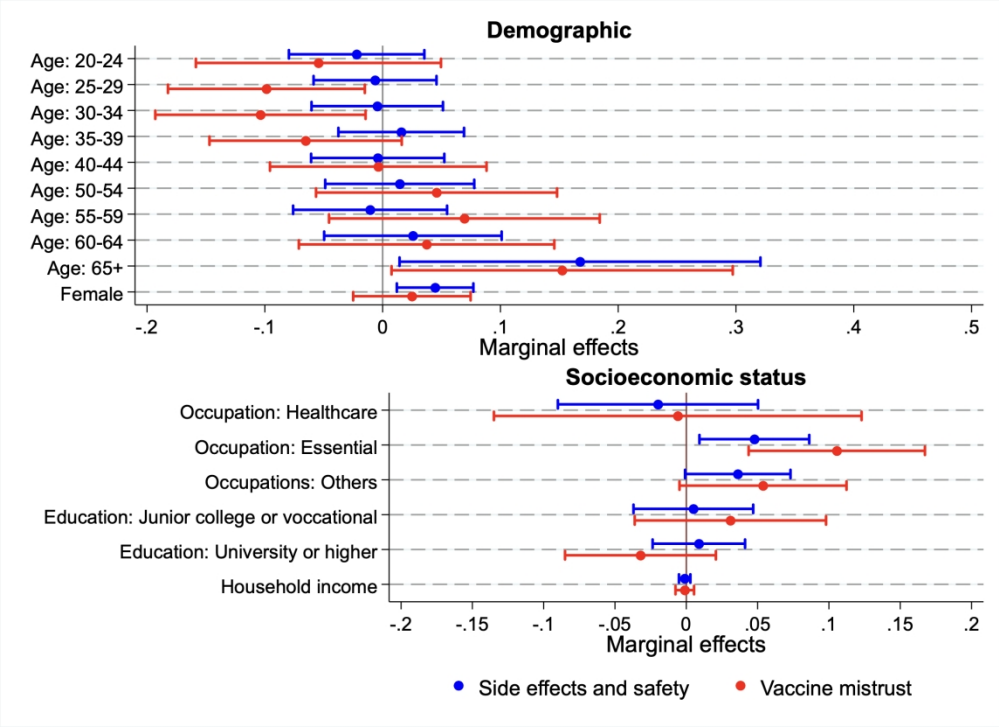
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

Figure 2. Determinants of reasons for vaccine hesitancy: Health-related and psychological/behavioural factors

Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for the residential area with the population weight for each age group; To have sufficient variability for estimates, those aged 65 or older were categorised into one group; 'Side effects and safety' denote vaccine hesitancy due to (a) concern about side effects and safety of the vaccine, (b) plan to wait and see if it is safe and may get it later, or (c) concern that the vaccine is being developed too quickly; 'Vaccine mistrust' denote vaccine hesitancy due to (a) do not like vaccines, (b) the vaccine could give me COVID-19, or (c) the vaccine will not work.

Figure 3. Effectiveness of vaccine passport

Note: Estimates among individuals who were undecided and unwilling to get vaccinated (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.



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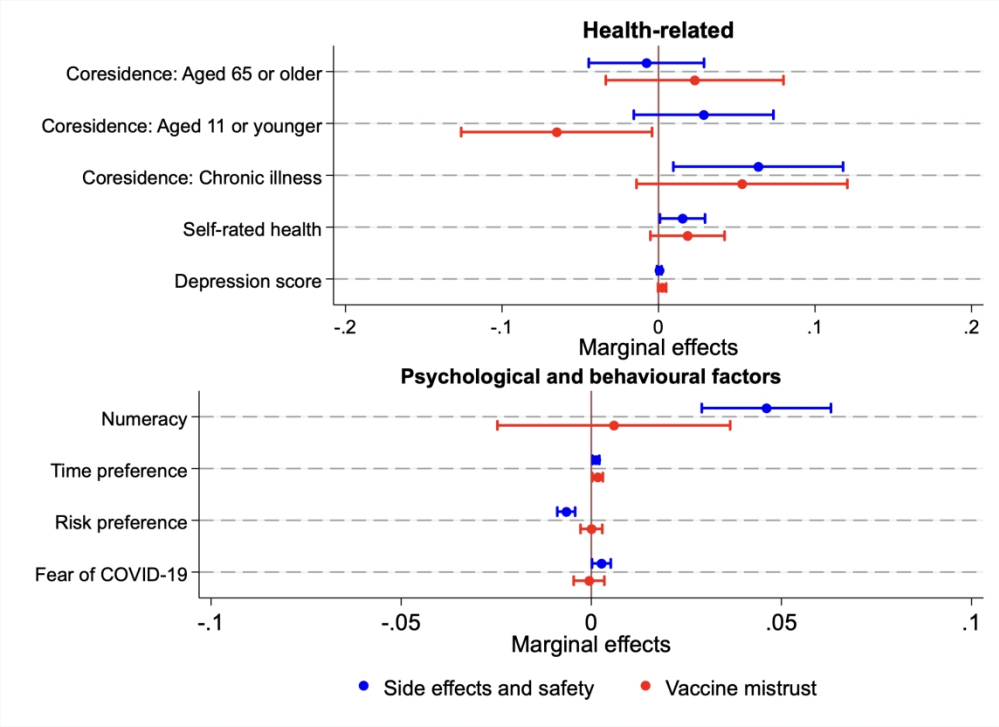

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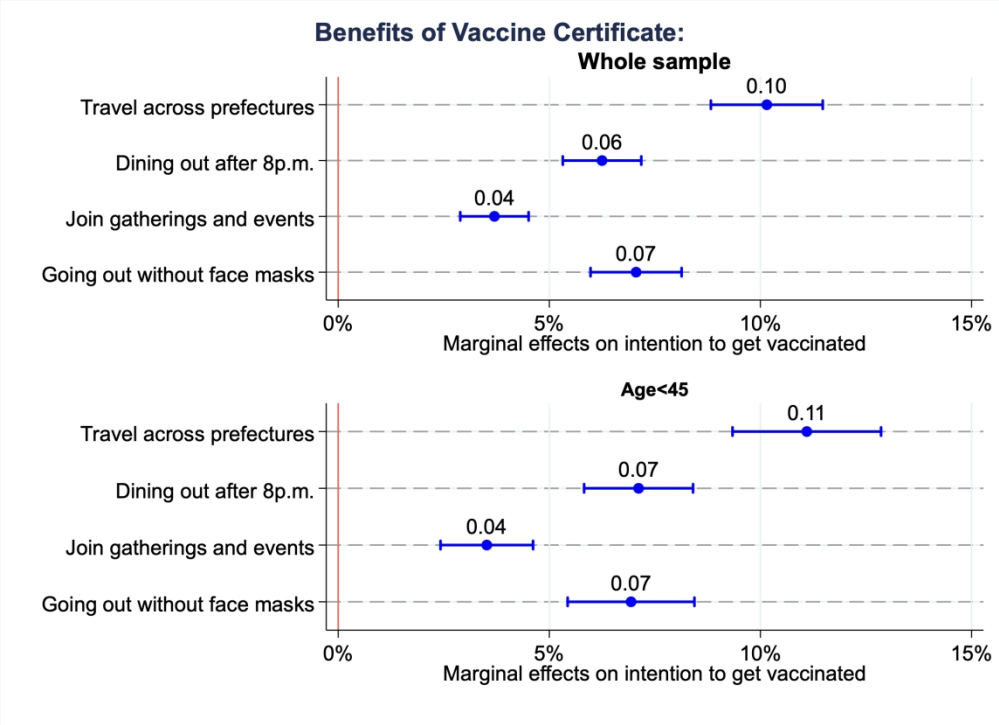

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Supplementary Material for

COVID-19 vaccine hesitancy and vaccine passports: A cross-sectional conjoint experiment in Japan

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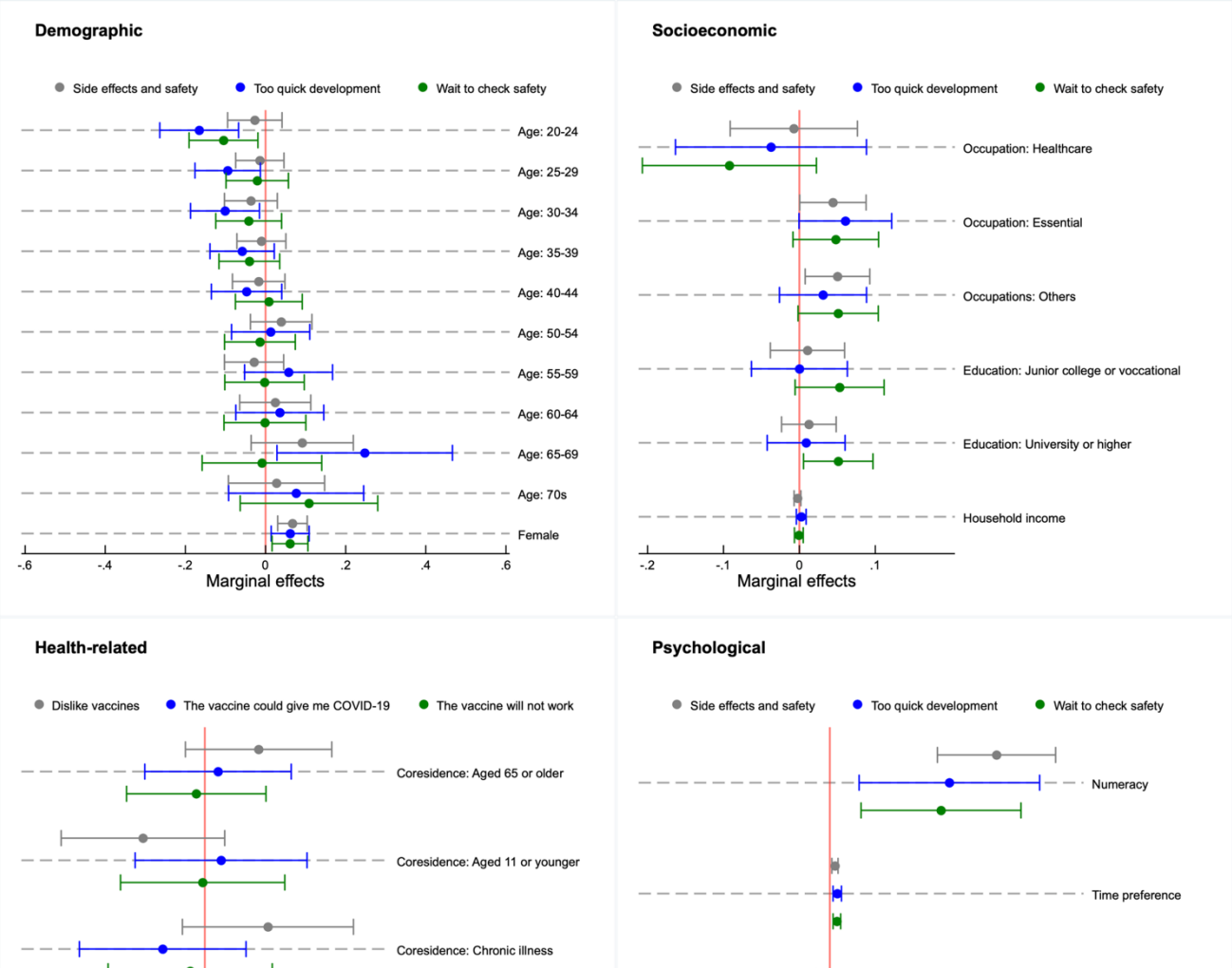
Contents

Appendix Table A-1. Determinants of vaccine hesitancy

	Will not get vaccinated		Undecided	
Vaccine hesitancy	Relative risk ratios	95%CI	Relative risk ratios	95%CI
Age (Ref. 45-49): 20-24	1.48	0.95 - 2.30	0.94	0.63 - 1.41
25-29	1.97**	1.36 - 2.85	1.83**	1.35 - 2.47
30-34	2.08**	1.40 - 3.09	1.47*	1.07 - 2.03
35-39	2.22**	1.55 - 3.18	1.63**	1.22 - 2.19
40-44	1.46	0.99 - 2.15	1.25	0.92 - 1.70
50-54	0.87	0.58 - 1.29	0.75	0.55 - 1.04
55-59	0.89	0.59 - 1.35	0.55**	0.38 - 0.78
60-64	0.53**	0.35 - 0.79	0.33**	0.23 - 0.47
65-69	0.24**	0.13 - 0.42	0.14**	0.08 - 0.23
70-74	0.30**	0.18 - 0.51	0.11**	0.07 - 0.20
Female	1.08	0.88 - 1.32	1.26**	1.06 - 1.51
Co-residence: Aged 65 or older	0.75*	0.60 - 0.95	0.91	0.74 - 1.11
Aged 11 or younger	0.68*	0.50 - 0.92	1.10	0.88 - 1.38
Chronic illness	0.53**	0.41 - 0.68	0.59**	0.47 - 0.73
Occupation: Healthcare worker	0.26**	0.16 - 0.43	0.20**	0.13 - 0.33
Other essential workers	0.56**	0.43 - 0.73	0.83	0.67 - 1.04
Other occupations	0.70**	0.55 - 0.89	0.88	0.71 - 1.09
Education: Junior college or vocational	0.82	0.63 - 1.07	0.87	0.69 - 1.10
University or higher	0.60**	0.48 - 0.75	0.74**	0.61 - 0.90
Household income	0.96*	0.94 - 0.99	0.94**	0.92 - 0.97
Self-rated health	0.79**	0.71 - 0.88	0.85**	0.78 - 0.92
K10 depression scale	1.01**	1.00 - 1.03	1.01	1.00 - 1.02
Statistical literacy	0.85**	0.75 - 0.96	1.05	0.94 - 1.17
Time preference	1.01*	1.00 - 1.01	1.01*	1.00 - 1.01
Risk preference	1.00	0.99 - 1.02	0.99	0.98 - 1.00
Fear of COVID-19	0.95**	0.93 - 0.97	0.99	0.98 - 1.01
Constant	3.01*	1.25 - 7.22	1.35	0.64 - 2.85
Observations	5,000			

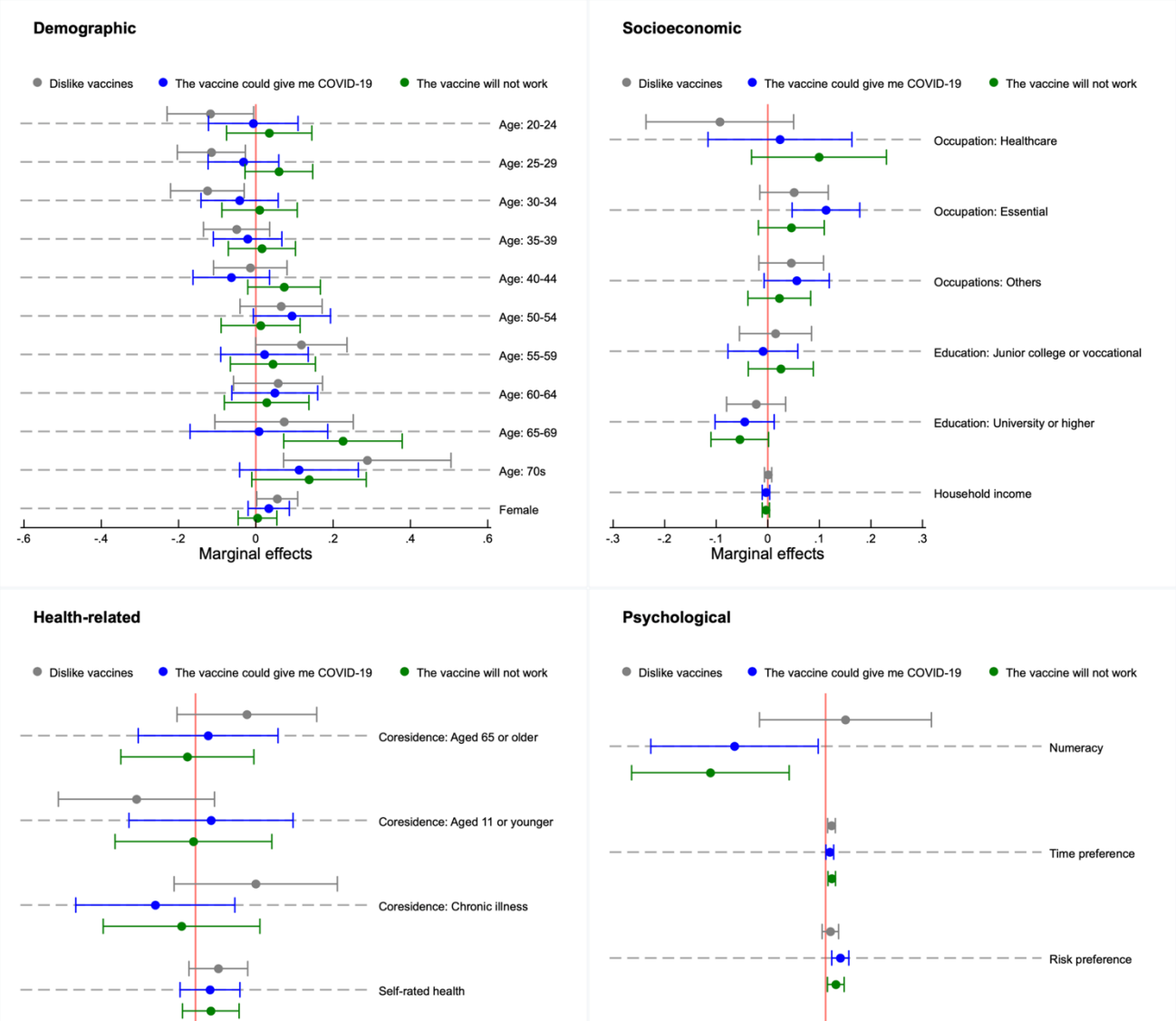
Note: The outcome reference is 'Willing to get vaccinated or have already vaccinated'; ** p<0.01, * p<0.05; 95% confidence intervals (CI) were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.

Appendix Figure A-1. Determinants of reasons for vaccine hesitancy: Vaccine safety and side effects



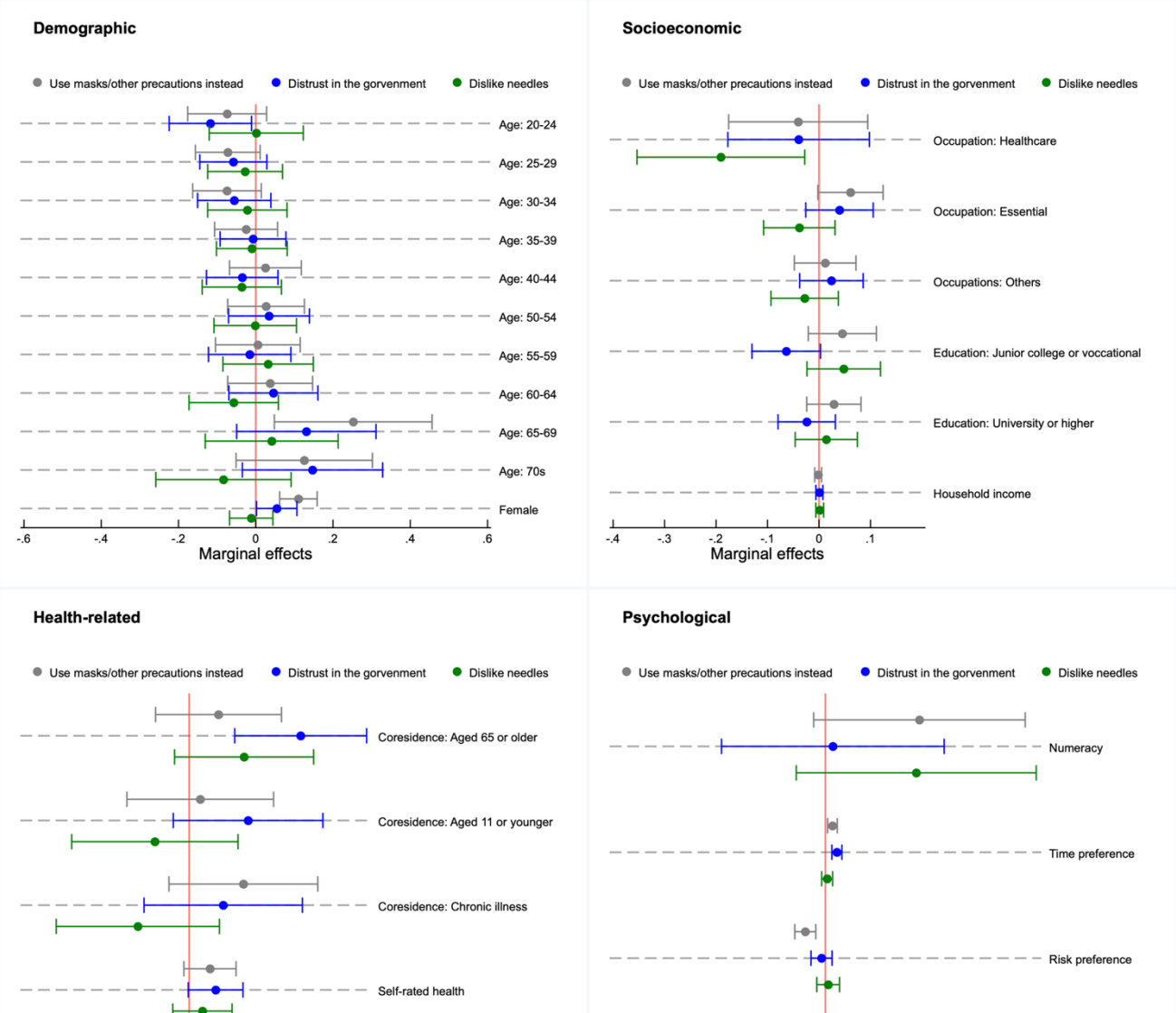
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-2. Determinants of reasons for vaccine hesitancy: Vaccine mistrust



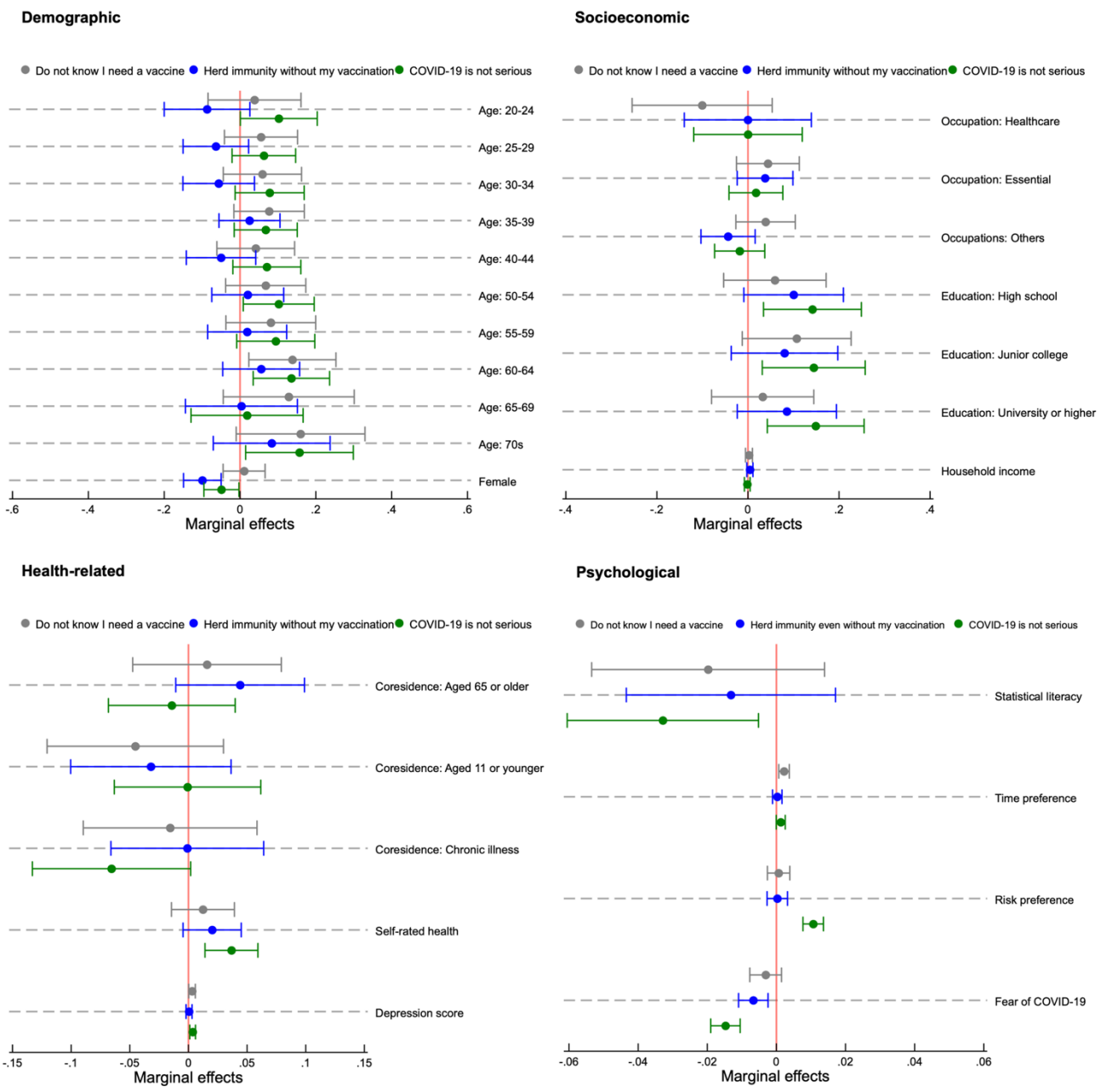
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-3. Determinants of reasons for vaccine hesitancy: Other mistrust



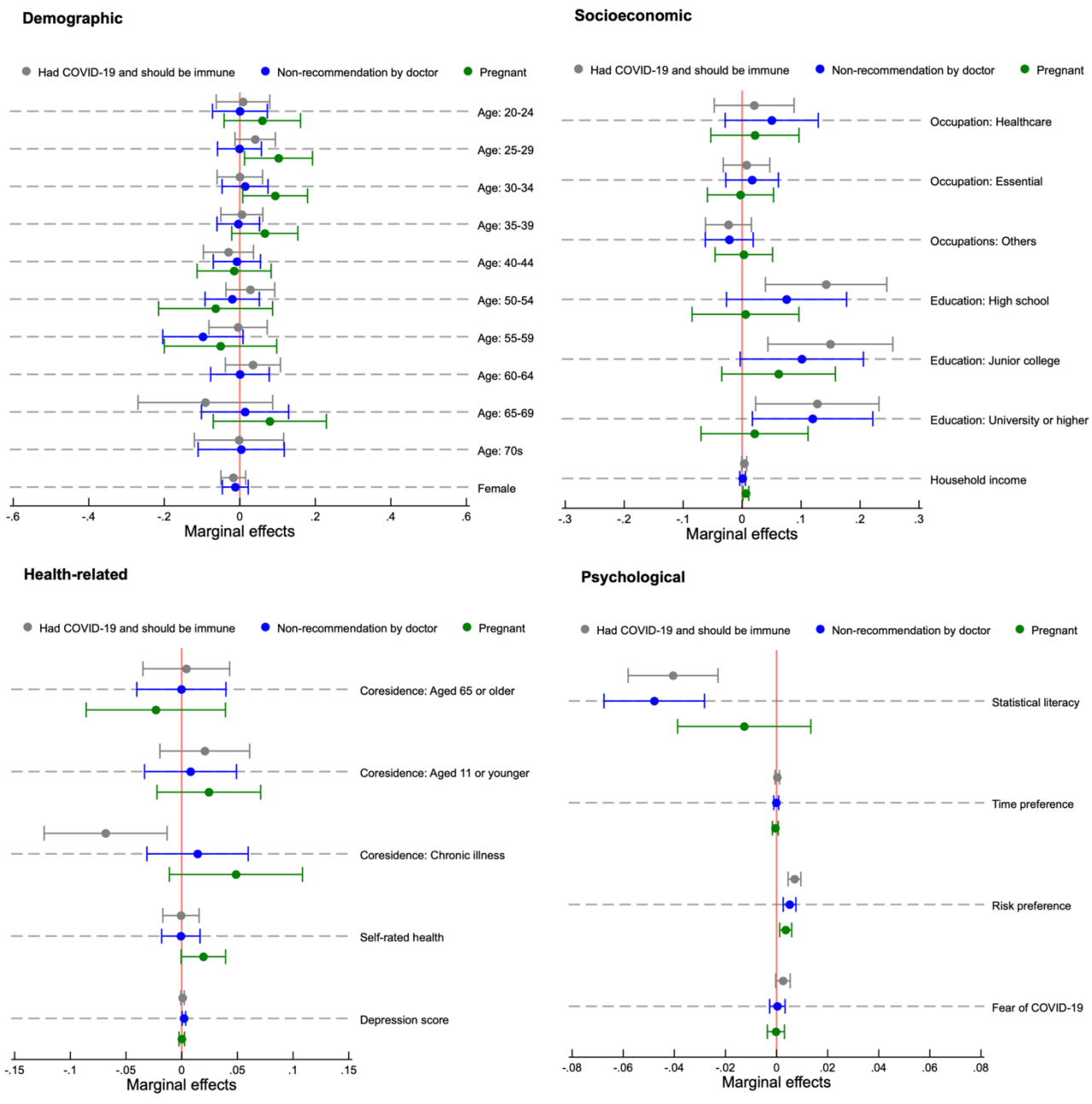
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for the residential area with the population weight for each age group.

Appendix Figure A-4. Determinants of reasons for vaccine hesitancy: Attitudes toward COVID-19



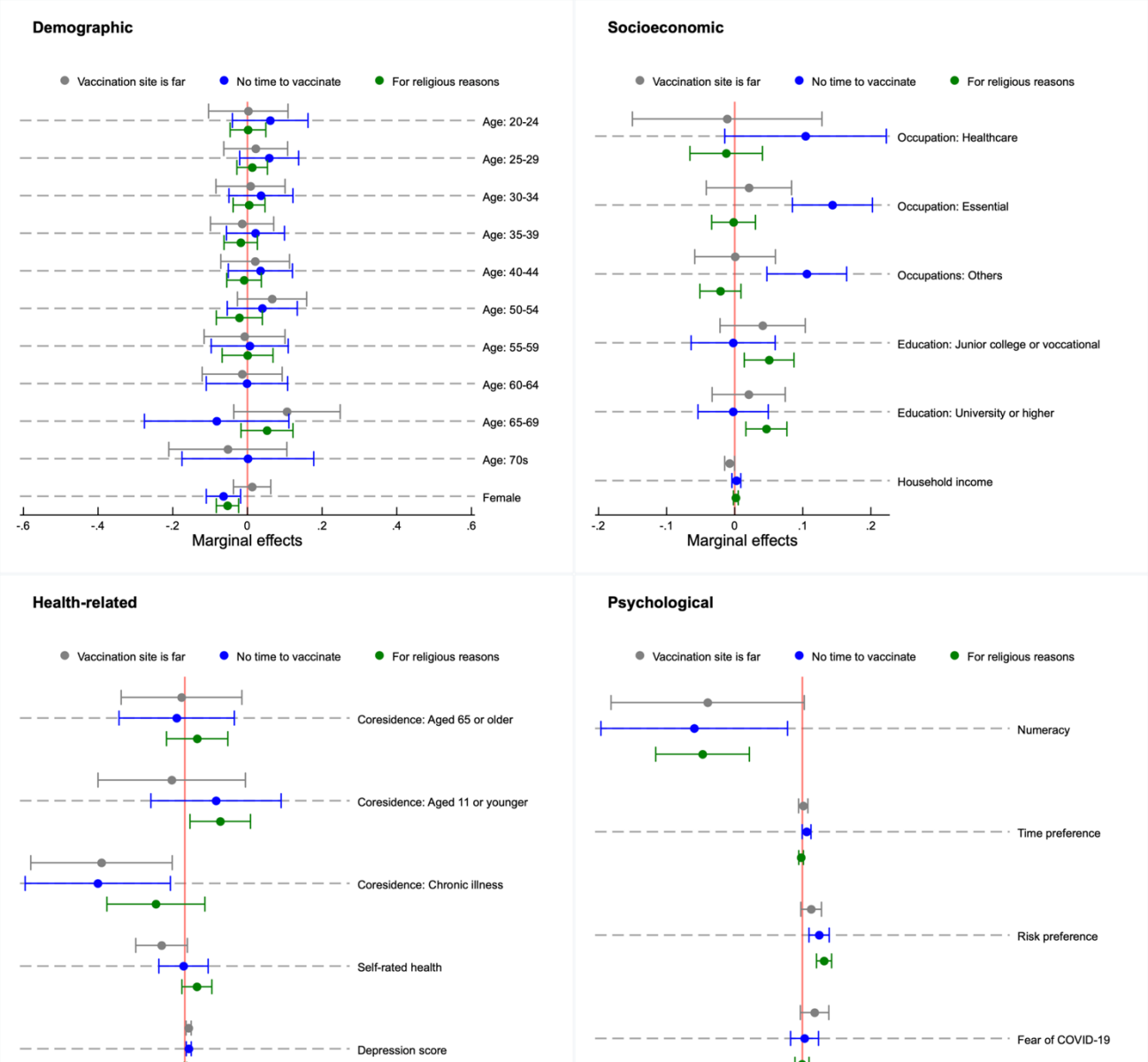
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-5. Determinants of reasons for vaccine hesitancy: Health-related reasons



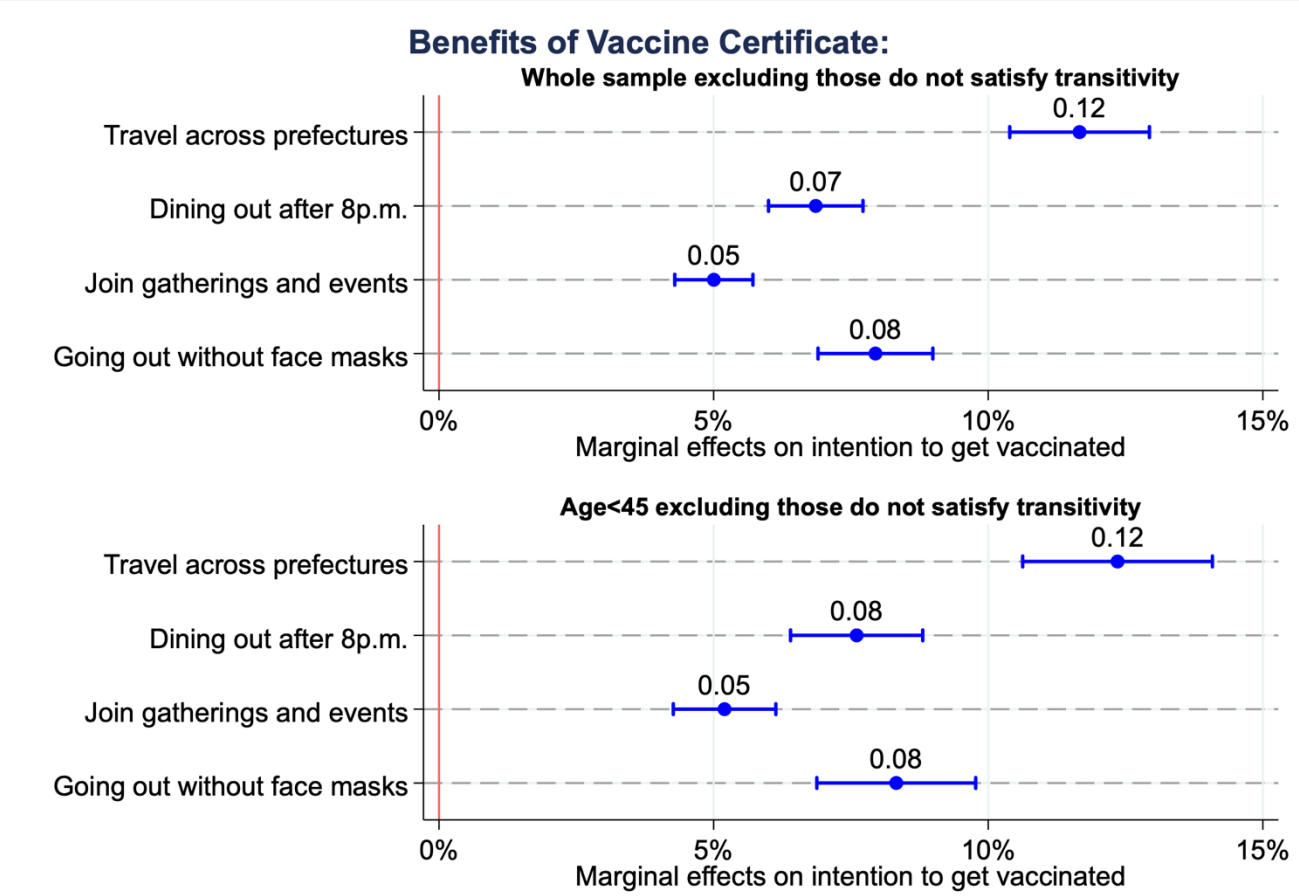
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-6. Determinants of reasons for vaccine hesitancy: Other reasons



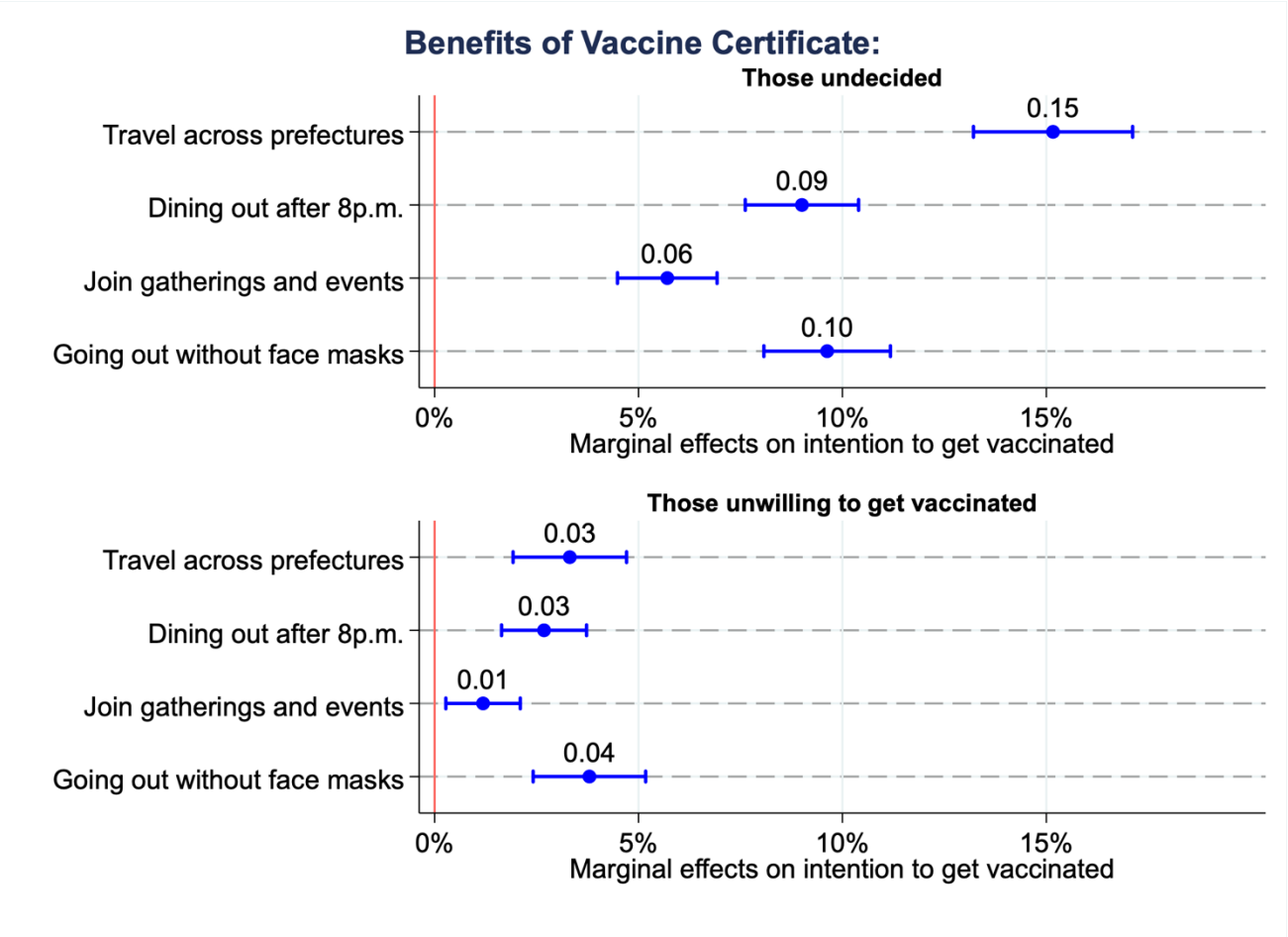
Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n= 1,518); Markers represent marginal effects with error bars showing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Adjusted for residential area with the population weight for each age group;

Appendix Figure A-7. Vaccine passport: Exclude those with non-transitive preferences



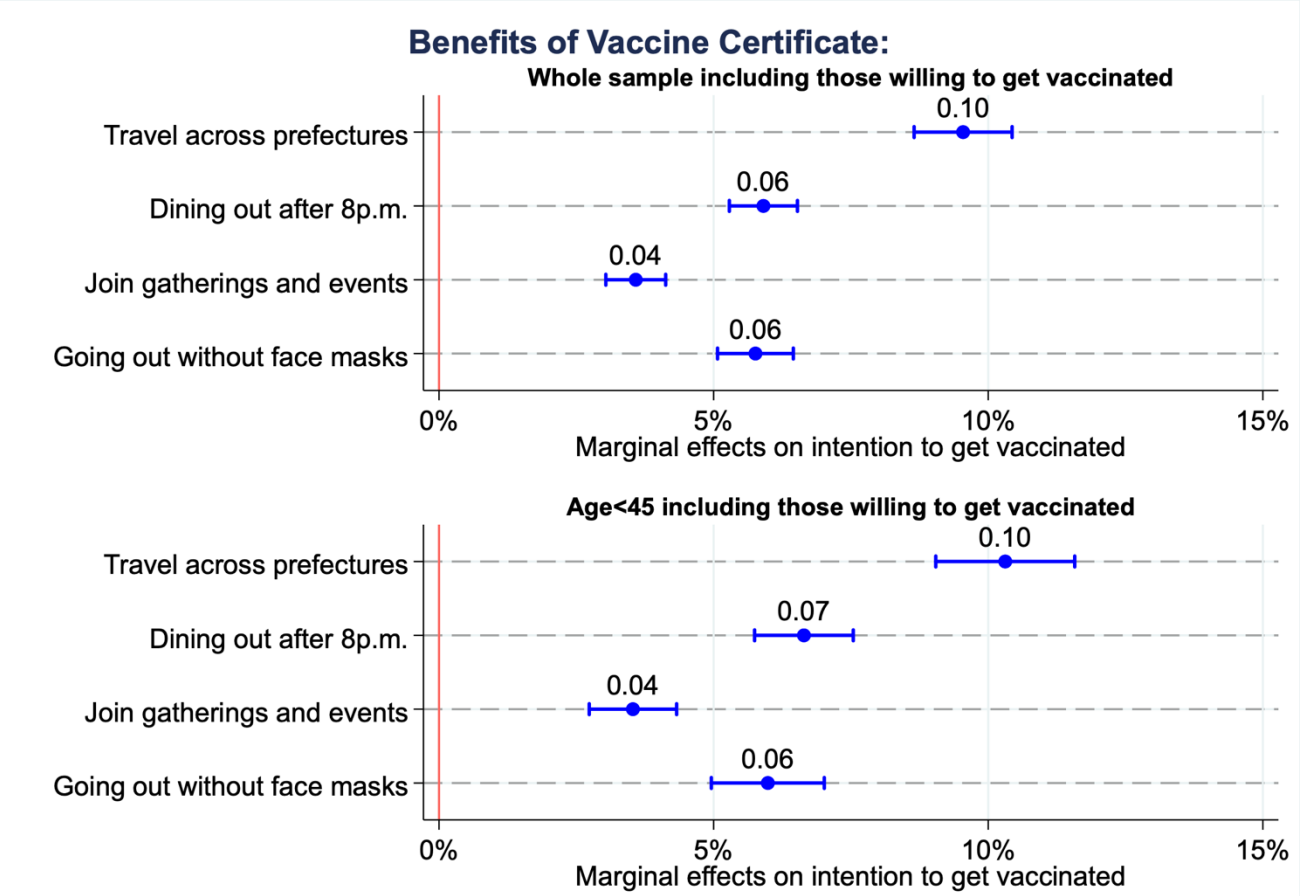
Note: Estimates among individuals who were undecided and unwilling to get vaccinated, excluding those who did not satisfy transitivity of the vaccine preference (n= 1,416 for all age groups and n= 815 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.

Appendix Figure A-8. Vaccine passport: Separate analyses of those undecided and unwilling to get vaccinated



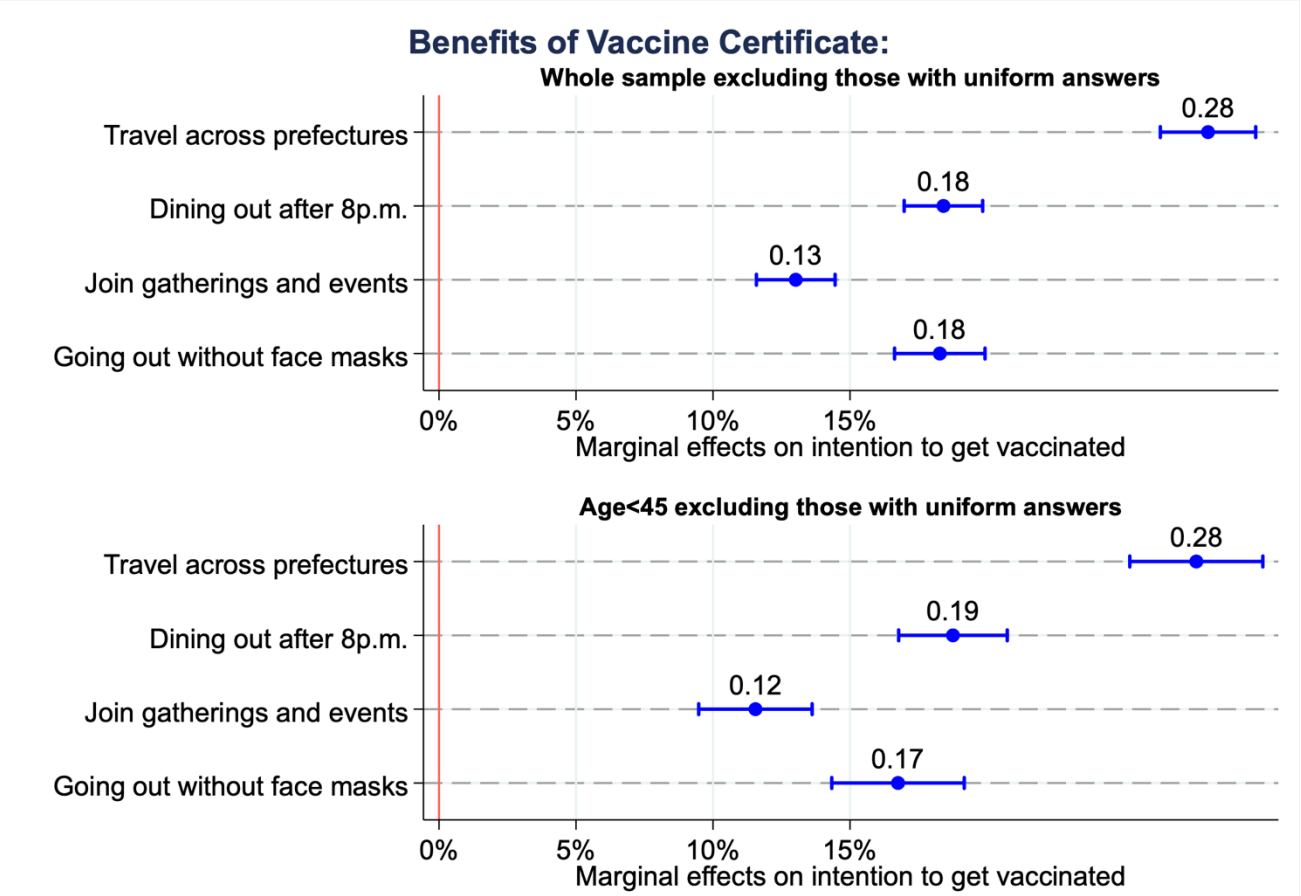
Note: Estimates among individuals who were unwilling to get vaccinated (n= 894 for those undecided to get vaccinated and n= 624 for those unwilling to get vaccinated); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.

Appendix Figure A-9. Vaccine passport: Include those willing to get vaccinated



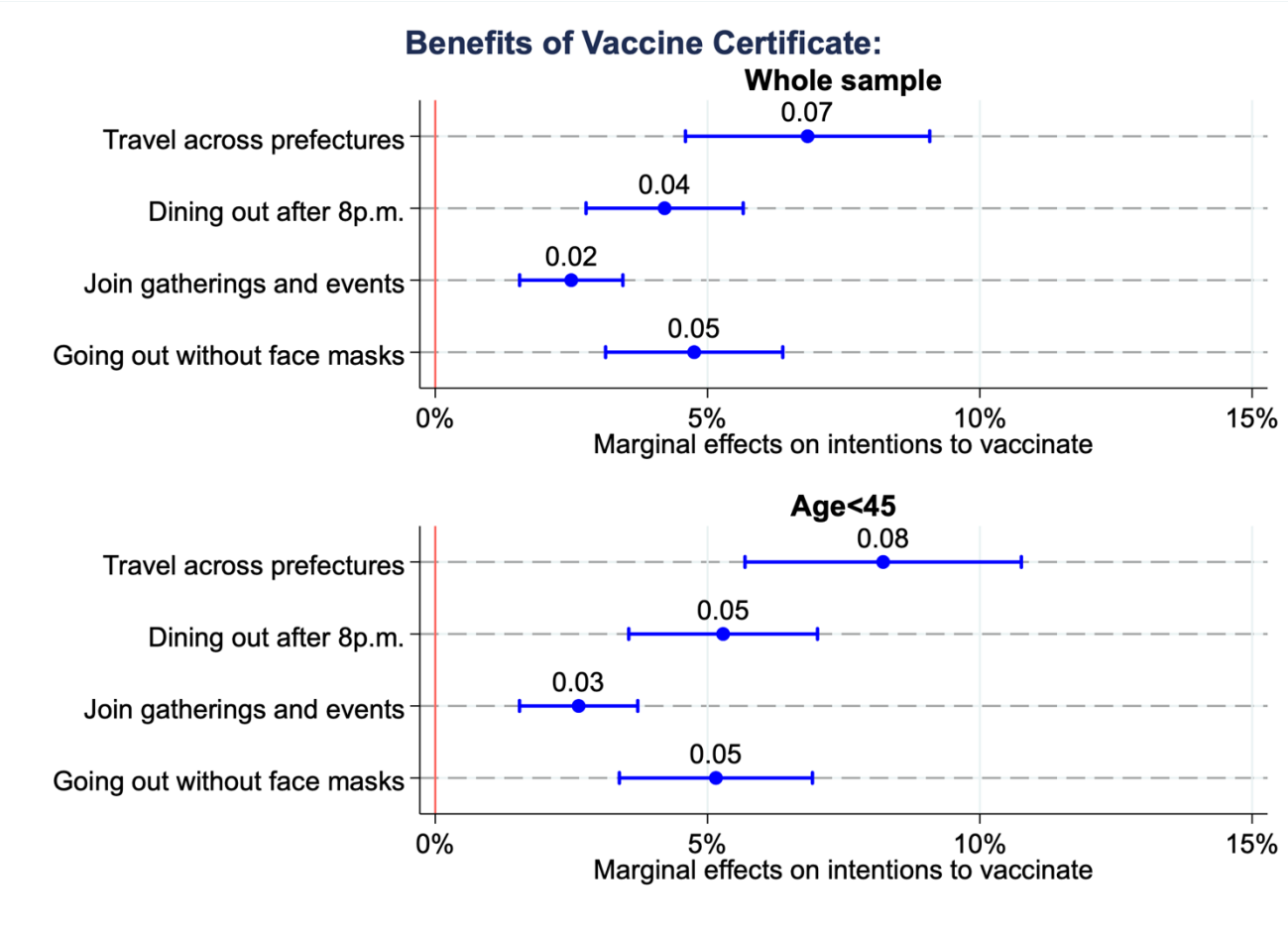
Note: Estimates among individuals who have not vaccinated yet, including 'Unwilling,' 'Undecided,' and 'Willing' (n= 3,171 for all age groups and n= 1,644 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.

Appendix Figure A-10. Vaccine passport: Exclude uniform individuals



Note: Estimates among individuals who were undecided and unwilling to get vaccinated, excluding those who provided uniform answers regarding their vaccination intentions regardless of available options (n= 1,531 for all age groups and n= 754 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.

Appendix Figure A-11. Vaccine passport: Estimates by multilevel mixed-effects logistic regression



Note: Estimated by multilevel mixed-effects logistic regression with random intercepts by individuals among those who were undecided and unwilling to get vaccinated (n= 1,518 for all age groups and n= 884 for those aged 45 or younger); Adjusted for age, gender, co-resident family members, occupation, education, income, health status, statistical literacy, time preference, risk preference, fear of COVID-19, residential area, and vaccine attributes with the population weight for each age group by region; Values and markers are marginal effects with bars representing 95% confidence intervals estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated; Full results are available upon request.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-9
Objectives	3	State specific objectives, including any prespecified hypotheses	9
Methods			
Study design	4	Present key elements of study design early in the paper	10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	10
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	11, 12
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*10-12*
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-14
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13, 14
		(*b*) Describe any methods used to examine subgroups and interactions	13, 14
		(*c*) Explain how missing data were addressed	NA
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	10

	(*e*) Describe any sensitivity analyses	14-17

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	14
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*NA*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*NA*
		Cross-sectional study—Report numbers of outcome events or summary measures	*14*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-18
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	18-19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20, 21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	21
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.