BMJ Open

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

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

To cite: Okamoto S, Kamimura K, Komamura K. COVID-19 vaccine hesitancy and vaccine passports: a cross-sectional conjoint experiment in Japan. *BMJ Open* 2022;**12**:e060829. doi:10.1136/bmjopen-2022-060829

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-060829).

Received 06 January 2022
Accepted 01 June 2022

[1]Research Team for Social Participation and Community Health, Tokyo Metropolitan Institute of Gerontology, Itabashi-ku, Tokyo, Japan
[2]Institute for Global Health Policy Research, National Center for Global Health and Medicine, Shinjuku-ku, Tokyo, Japan
[3]Research Center for Financial Gerontology, Keio University, Minato-ku, Tokyo, Japan
[4]Hirao School of Management, Konan University, Nishinomiya, Hyogo, Japan
[5]Faculty of Economics, Keio University, Minato-ku, Tokyo, Japan

Correspondence to
Dr Shohei Okamoto;
shohei@z2.keio.jp

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 5000 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 to 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 5000 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 Novel 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 (eg, 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 WHO,[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 one-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, sociocultural, 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

Sociodemographic 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 with their younger counterparts and men compared with 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]

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 sociodemographic 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 towards 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 (ie, 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 (ie, 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 policy-makers,[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 sociodemographic 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 sociodemographic, 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 use 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 policy-makers 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 5000 Japanese adults aged 20–74 from an online survey conducted from 21 July 2021 to 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 (ie, 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 (ie, Hokkaido, Tohoku, Kanto except for the Tokyo Metropolitan Area, Tokyo Metropolitan Area, Chubu, Kinki, Chugoku, Shikoku and Kyusyu) and eleven categories for each 5 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 (eg, Saitama and Kanagawa), Kinki (for example, Osaka) and Kyushu (for example, Okinawa).

About 4 months after this survey (ie, between 10 November 2021 and 20 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 4367 responses out of 5000 participants in the first wave (87.3%).

COVID-19 situation in Japan

During the survey, approximately 5000 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' (ie, closed spaces, crowded places and close-contact settings) and ensuring adequate ventilation.

Patient and public involvement statement

There was no patient and public involvement in this study.

Definitions of variables

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 be vaccinated 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.

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, coresident 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, front-line essential workers and other workers, following existing definitions by the Centers for Disease Control and Prevention.[38] Specifically, front-line essential workers include those working in manufacturing, wholesale/retail, transportation/shipping/postal services, education, primary industry and critical infrastructure (ie, 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] The time preference and risk attitudes, 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 attitude 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 1000 would be expected to get the disease?; (2) If five people all have the winning number in the lottery and the prize is US$2 million, how much will each of them get?; (3) Let's say you have US$200 in a savings account. The account earns 10% interest per year. How much would you have in the account at the end of 2 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.

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 (ie, 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).

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 (ie, 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 (ie, 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.

Conjoint analysis: vaccine passport

To evaluate the association between the relaxation of public health restrictions by vaccine passports and vaccine acceptance, we used a conjoint experimental design.[18 46] The conjoint experiment is useful in assessing the effects of varied attributes at different levels, with the reduced

Table 1 Conjoint experimental design

	Available relaxations of restrictions by vaccine passports				Vaccination intensions
	Travel across prefectures	Dining out after 20:00 hour	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	○	○	○	○	

number of necessary assignments using an orthogonal table.

To develop conjoint tasks, we followed the The Professional Society for Health Economics and Outcomes Research's (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 SEs and considering logit models with binominal distributions of outcomes.

To assess potential heterogeneity across individual characteristics, we further conducted a subgroup 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: (1) analysis without the respondents whose choices may have been nontransitive; (2) separate analysis for respondents who were undecided and unwilling to be vaccinated; (3) analysis including respondents who intended to be vaccinated earlier or had already been vaccinated; (4) analysis without those who provided a uniform answer to all options; (4) analysis by a multilevel mixed-effects logistic regression to relax the assumption of the independence of irrelevant alternatives. Regarding the robustness test (1), 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 reanalysed the association by excluding them, assuming that their choices were irrational. For the robustness test (3), from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (ie, all yes or no), to focus solely on individuals whose intention changed with vaccine passports.

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.

Table 2 Descriptive statistics (n=5000)

Variable	Mean or proportion	SD
Vaccine intentions		
No	12.5%	
Undecided	17.9%	
Yes	33.1%	
Already vaccinated	36.6%	
Age	48.40	14.80
Female	50.3%	
Coresidence		
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 attitudes	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%	

K10, Kessler Psychological Distress Scale.

All analyses were conducted using Stata MP, V.17.0 (StataCorp).

RESULTS

Descriptive statistics

Table 2 summarises the descriptive statistics of the sample. Out of a total of 5000 respondents, approximately 30% hesitated to be vaccinated (ie, 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 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 1518 respondents hesitating vaccination.

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.

Determinants of vaccine hesitancy

Table 4 shows the determinants of vaccine hesitancy. Compared with those aged 45–49, younger people aged 25–44 were likely to hesitate to get vaccinated, resulting in estimated ORs ranging between 1.32 and 1.87, with 95% CIs 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

Table 4 Determinants of vaccine hesitancy

Vaccine hesitancy	OR	95% CI
Age (Ref. 45–49)		
20–24	1.13	0.82 to 1.58
25–29	1.87**	1.44 to 2.44
30–34	1.67**	1.26 to 2.21
35–39	1.83**	1.42 to 2.36
40–44	1.32*	1.01 to 1.73
50–54	0.79	0.60 to 1.04
55–59	0.67**	0.50 to 0.89
60–64	0.40**	0.30 to 0.53
65–69	0.17**	0.11 to 0.26
70–74	0.18**	0.12 to 0.27
Female	1.18*	1.02 to 1.37
Co-residence		
Aged 65 or older	0.84*	0.71 to 1.00
Aged 11 or younger	0.92	0.76 to 1.13
Chronic illness	0.56**	0.47 to 0.67
Occupation		
Healthcare worker	0.23**	0.16 to 0.33
Frontline essential workers	0.71**	0.59 to 0.86
Other occupations	0.80*	0.67 to 0.95
Education		
Junior college or vocational	0.85	0.70 to 1.03
University or higher	0.68**	0.58 to 0.80
Household income	0.95**	0.93 to 0.97
Self-rated health	0.82**	0.76 to 0.89
K10 depression scale	1.01**	1.00 to 1.02
Statistical literacy	0.96	0.87 to 1.05
Time preference	1.01**	1.00 to 1.01
Risk attitudes	1.00	0.99 to 1.01
Fear of COVID-19	0.97**	0.96 to 0.99
Constant	3.91**	2.07 to 7.42
Observations	5000	

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'; 95% CIs were estimated by robust standard errors; Adjusted for residential area with the population weight for each age group by region.
*p<0.01, **p<0.05.

to 0.89. Female respondents tended to express vaccine hesitancy more than their male counterparts (OR 1.18, 95% CI 1.02 to 1.37). Additionally, those living with older adults and members with chronic illness tended to accept vaccination with higher probabilities compared with their counterparts not living with these population categories.

Socioeconomic factors are also associated with vaccine hesitancy. Healthcare workers, front-line essential workers and those performing paid work were likely to be non-vaccine-hesitant compared with non-employed individuals: the former two groups were more likely to accept vaccination, showing ORs of 0.23 (95% CI 0.16 to 0.33) and 0.71 (95% CI 0.59 to 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 to 0.89) and OR 1.01 (95% CI 1.00 to 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 (online supplemental appendix table A-1).

Reasons for vaccine hesitancy

In figures 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 (ie, individuals aged 25–29 and 30–34).

Additionally, the results for the determinants of vaccine hesitancy due to each reason are shown in online supplemental appendix figures A1–A6. 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 restriction and vaccine acceptance, suggesting that relaxing each restriction 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% to 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.

Additionally, we conducted the following five robustness tests. First, we excluded the respondents whose choices may have been non-transitive. However, the results remained unchanged (online supplemental

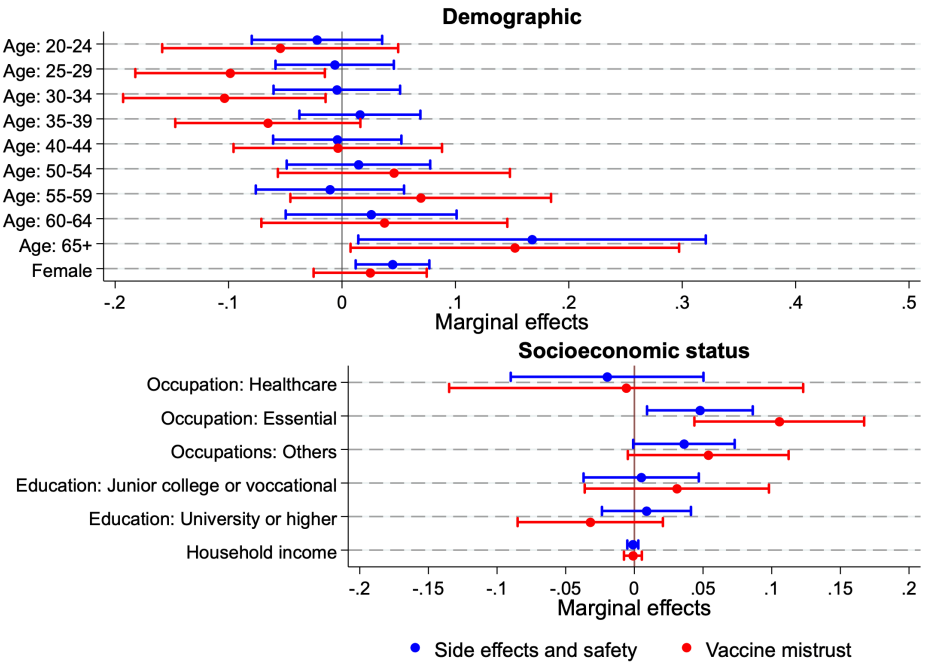

Figure 1 Determinants of reasons for vaccine hesitancy: Demographic and socioeconomic factors. Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n=1518); Markers represent marginal effects with error bars showing 95% CIs estimated by robust SEs; Marginal effects denote 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.

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 (online supplemental appendix figure A-8). Third, we included respondents who intended to get vaccinated earlier or had already been vaccinated, and the same results were still observed (online supplemental appendix figure A-9). Next, from among the individuals hesitating to be vaccinated, we excluded those who provided a uniform answer to all options (ie, all yes or no), the results remained unchanged (online supplemental 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 (online supplemental 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.

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

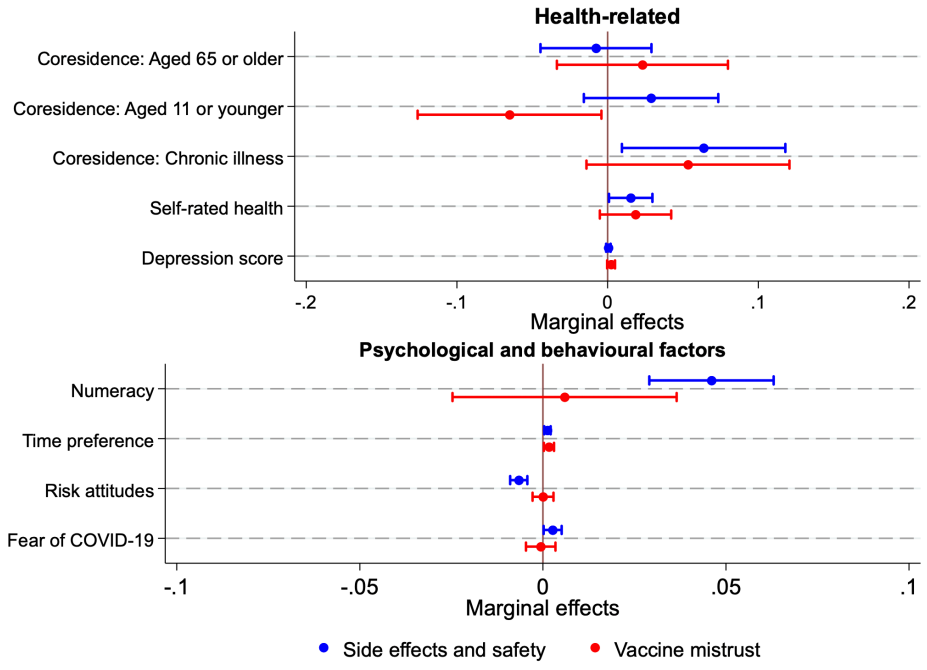

Figure 2 Determinants of reasons for vaccine hesitancy: Health-related and psychological/behavioural factors. Note: Analyses among individuals who were undecided and unwilling to get vaccinated (n=1518); Markers represent marginal effects with error bars showing 95% CIs estimated by robust SEs; Marginal 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.

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 (eg, 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. Using behavioural insights, better designs on how to best communicate with people to enhance vaccine

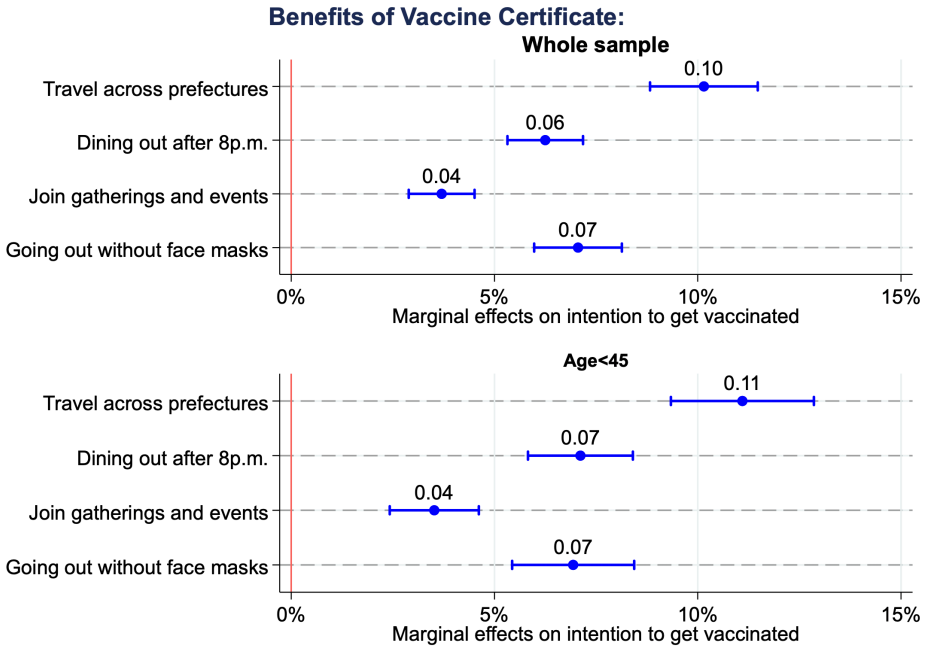

Figure 3 Effectiveness of vaccine passport. Note: Estimates among individuals who were undecided and unwilling to get vaccinated (n=1518 for all age groups and n=884 for those aged 45 or younger); Adjusted for age, gender, coresident family members, occupation, education, income, health status, statistical literacy, time preference, risk attitudes, 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% CIs estimated by robust standard errors; Marginal effects denote differences in the probability of being willing to get vaccinated. Full results are available on request.

uptake should be considered.[23 24] Second, emphasising benefits other than health (eg, 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

Table 5 Stated and revealed intention to vaccination

Wave1/wave 2	Vaccinated, %	Intend to get vaccinated, %	Undecided, %	Unwilling, %	Total
Intend to get vaccinated	94.9	2.9	1.3	1.0	1424
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	2718

Note: Wave1 was conducted between 21 July 2021 and 23 July 2021, while wave 2 was held between 10 November 2021 and 20 November 2021 as a follow-up survey of wave1.

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 with 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 towards 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 towards 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.

Acknowledgements The authors thank Dr Rei Goto, Dr Hirotaka Kato, Mr Shingo Kasahara, Mr Tatsunari Miyayama, and Ms Tomomi Maeda at Keio University for their helpful feedback. The authors are grateful to Ms Haruka Umijima at Keio University for her administrative assistance when conducting the study.

Contributors SO, KKa and KKo conceptualised the study and were engaged in the data collection. SO and KKa conducted analyses, which were further refined and finalised by SO. KKo also provided critical comments to refine the analyses. SO prepared a first draft, which was reviewed by KKa and KKo. SO is responsible for the overall content as the guarantor.

Funding This research is supported in part by a Grant-in-Aid for JSPS Fellows (No. 20J00394), the Murata Science Foundation (No. Not Applicable), and the Research Centre for Financial Gerontology of Keio University (No. Not Applicable). However, none of them was involved in conceptualisation, design, data collection, analysis, the decision to publish or preparation of the manuscript.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the Institutional Review Board of the Institute of Economics Studies, Keio University (No. 21 009R and 21 011R). 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.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. 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.

ORCID iDs
Shohei Okamoto http://orcid.org/0000-0002-8580-5291
Kazuki Kamimura http://orcid.org/0000-0002-4404-799X

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