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A high level of vaccine knowledge increases people's behavioral risks for contracting COVID-19 in Japan

Shuko Takahashi [a,b,*], Shohei Yamada [c], Satoshi Sasaki [d], Naomi Takahashi [e], Masaru Nohara [f], Ichiro Kawachi [g]

[a] Office of Medical Policy, Department of Health and Welfare, Iwate Prefectural Government, 10-1 Uchimaru, Morioka, Iwate, 020-8570, Japan
[b] Division of Medical Education, Iwate Medical University, 1-1-1, Idaidori, Yahaba-cho, Shiwa-gun, Iwate, 028-3694, Japan
[c] Division of Finance, Department of General Affairs, Iwate Prefectural Government, 10-1 Uchimaru, Morioka, Iwate, 020-8570, Japan
[d] Division of Health and National Health Insurance, Department of Health and Welfare, Iwate Prefectural Government, 10-1 Uchimaru, Morioka, Iwate, 020-8570, Japan
[e] Department of Hygiene and Preventive Medicine, Iwate Medical University, School of Medicine, 1-1-1, Idaidori, Yahaba-cho, Shiwa-gun, Iwate, 028-3694, Japan
[f] Department of Health and Welfare, Iwate Prefectural Government, 10-1 Uchimaru, Morioka, Iwate, 020-8570, Japan
[g] Department of Social and Behavioral Sciences, Harvard. T.H. Chan School of Public Health, 401 Park Drive, Boston, MA, 02215, USA

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ABSTRACT

Background: There has been no study in which the association between levels of vaccine knowledge and preventive behaviors was examined during the COVID-19 pandemic. We examined the transition to risky (transmission) behavior according to level of vaccine knowledge over a seven-month period when vaccines became widely available in Japan.

Methods: A series of cross-sectional surveys were conducted using rapid online surveys of residents in Iwate Prefecture from December 4 to 7 in 2020 (the first survey) and from July 2 to 4 in 2021 (the fourth survey). We calculated each individual's risk of acquiring SARS-CoV-2 infection using a quantitative assessment tool (the microCOVID calculator). The respondents' level of knowledge regarding the COVID-19 vaccine was assessed by a questionnaire and was divided into four groups: very low level, low level, moderate level, and high level of vaccine knowledge.

Results: People with a high-level knowledge about the vaccine had significantly higher odds ratios (ORs) of transitioning to high-risk behavior compared to people with a low level of vaccine knowledge (OR [95% confidence interval (CI)], 1.50 [1.17–1.93]; P = 0.001). There was a dose-response association according to the four levels of vaccine knowledge, while engagement in preventive measures in the first survey was not associated with high-risk behavior in the follow-up survey.

Conclusions: Since new variants of SARS-CoV-2 have evolved, policy makers should continue to communicate strong messages to keep a high level of consciousness and maintain basic preventive measures even after widespread vaccination.

1. Introduction

Since the first case of SARS-CoV-2 infection was identified in Wuhan, China, cases rapidly spread to the rest of the globe. The World Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020. In Japan, the first case of COVID-19 was confirmed on January 16, 2020, and cases spread from urban areas to rural areas and even to remote islands of Japan. The worldwide death toll from COVID-19 as of November 11, 2021 is 5,072,682 (Johns Hopkins University and Medicine, 2021a) and the death toll in Japan is 18,310 (Ministry of Health, Labour and Welfare, 2021).

Preventative behaviors for avoiding contracting the disease are well understood, including wearing facial masks, washing hands, physical distancing and avoiding crowds. However, several studies have

Abbreviations: ORs, odds ratios; WHO, World Health Organization; CI, confidence interval.

* Corresponding author. Office of Medical Policy, Department of Health and Welfare, Iwate Prefectural Government, 10-1 Uchimaru, Morioka, Iwate, 020-8570, Japan.

E-mail address: shutakahashi-iwt@umin.ac.jp (S. Takahashi).

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indicated variations in the tendency to follow protective measures according to people's demographic characteristics (age and sex), socioeconomic status (occupation and educational attainment), and political beliefs (An et al., 2020; X. Chen and Chen, 2020; Li et al., 2020; Shahnazi et al., 2020).

Meanwhile, effective vaccines are a potential game-changing approach to bring the pandemic under control (World Health Organization, 2021). Vaccination for COVID-19 started in late 2020. Several vaccines have worked as well in real-world conditions as they did in clinical trial settings (Centers for Disease Control and Prevention, 2021a). As of November 11, 2021, more than 3.1 billion people worldwide (40.54% of the world's population) have been fully vaccinated (Johns Hopkins University and Medicine, 2021b). The Japanese vaccination rollout was initially delayed relative to other developed countries due to several factors, e.g., the insistence of Japanese government that vaccine safety & efficacy be demonstrated first in domestic clinical trials, and reluctance to change the law that shots could be given only under the supervision of physicians (Gordon and Reich., 2021). Subsequently, the pace of vaccination was accelerated with a strong push for mass-vaccination from the Japanese government (and cooperation from many workplaces). Nonetheless, only 10.5% of the total population had been vaccinated by the end of June 2021 (Government CIOs' Portal, 2021). Moreover, evolving SARS-CoV-2 variants are a growing threat to not only unvaccinated people but also those who have been vaccinated (Moore and Offit, 2021). With the emergence of the Delta variant, it is speculated that herd immunity will be difficult to achieve even with 70% coverage of the population. Although vaccines on the market have been demonstrated to be highly effective in reducing the risk of infection (Centers for Disease Control and Prevention, 2021b), WHO has urged the continuing use of preventive measures such as wearing facial masks and social distancing even after vaccination (World Health Organization, 2021).

Traditional theories of behavior propose that propose that people protect themselves based cognitive factors such as threat appraisal (Protection Motivation Theory) or perceived susceptibility/severity of an illness (Health Belief Model) (Glanz et al., 2008). According to this perspective, increasing the accuracy of people's perceptions about the threat or severity of an illness ought to elevate the likelihood that they will adopt steps to protect themselves.

In support of these traditional health behavior theories, a number of studies have found a link between COVID-19 knowledge and avoidance of risk behaviors. For example, Chen et al. used Protection Motivation Theory to explain the association between COVID-19 knowledge and adoption of preventive behaviors, including intention to get vaccinated (Chen et al., 2021). Motoki et al. used the information-deficit model to examine whether scientific literacy and perceived level of knowledge about COVID-19 are associated with attitudes toward COVID-19 vaccinations and preventive behaviors (Motoki et al., 2021).

Risk compensation theory provides an additional twist to the foregoing theories of behavior change, arguing that some individuals may adjust their behavior in response to changes in the perceived level of risk – i.e., taking more risks if they feel protected. For example, some patients relax dietary restrictions (avoiding bacon and eggs) once they initiate statin therapy, or some people may start to take more airplane trips after they are vaccinated against the SARS-CoV-2. Although the extra risks are usually small in comparison to the fundamental benefits of safety interventions, they may result in a lower net benefit than expected.

Hence we sought to test alternative theories by examining whether individuals with a high level of vaccine knowledge are also more (or less) likely to practice other preventive behaviors, such as avoiding crowded indoor places. Theories such as the Health Belief Model would predict that an individual with accurate perception of vaccine effectiveness would simultaneously practice protective behaviors such as social distancing. The reason is because the course of action a person takes in preventing illness relies on consideration of both perceived susceptibility and perceived benefit, such that the person would accept all recommended health actions if they were perceived as beneficial. By contrast, risk compensation theory would predict that if an individual (accurately) perceives that the vaccine will protect them from infection, they may relax other preventive practices.

The aim of our study was therefore to determine whether levels of vaccine knowledge was associated with changes in people's risk behavior over a period of seven months when vaccines became widely available in Japan.

2. Materials and methods

2.1. Study area

Iwate Prefecture is located in the northeastern part of Japan (about 500 km from Tokyo) with a population of about 1.2 million. The total number of COVID-19 cases as of August 12, 2021 was 2,335, including 47 cases of COVID-19-related deaths (Iwate Prefectural Government, 2021).

2.2. Data

Since the beginning of the pandemic, rapid online surveys of residents in Iwate Prefecture have been conducted by the Office of Medical Policy in the Department of Health and Welfare in Iwate Prefectural Government using a popular social network platform called LINE (LINE Corporation, Tokyo, Japan). The daily surveys capture information about new cases as well as characteristics of patients. A series of cross-sectional surveys were started in December 2020 to surveil people's behaviors during the pandemic. These surveys have been conducted every two months. An online questionnaire was administered to a total of 100,958 people who had registered by the time of the baseline survey. We sent out notification about the survey via the LINE platform on December 4, 2020, and 25,411 individuals responded from December 4 to 7 (response rate, 25.2%). We conducted a fourth survey of registered people from July 2 to 4, 2021. We analyzed panel data from these two surveys (December 2020 and July 2021). Fig. 1 summarizes the process by which we selected the 8,273 participants for whom panel data were available to look at changes in COVID preventive practices over time.

2.3. Outcome

We applied a weighting system called microCOVID to calculate the level of behavioral risk for acquiring COVID-19 (The microCOVID Project, 2020). microCOVID is a calculator to numerically quantify the risk of getting COVID-19 from daily activities. A score of 1.0 microCOVID is equivalent to a one-in-a-million chance of getting COVID. microCOVIDs are computed by using three major factors: activity risk, person risk, and number of people with whom an individual interacts (Supplementary Text 1). We obtained the microCOVID values for each person with the score = activity risk x number of people x person risk.

Activity risk indicates the chance that an activity will result in the transmission of SARS-CoV-2 from a person who is currently infected with the virus. According to microCOVID, the transmission risk is estimated to be "about 9% per hour" from spending more than 10 min indoors or in close proximity with an unmasked person who is COVID-19-positive. Coefficients of risk were assigned to other types of interaction which differ from that reference value. The weighting coefficients were calculated on the basis of the following factors: duration of interaction, mask wearing (respondents and other persons), indoor/outdoor environment, distance from each other, volume of conversation, and frequency of risky situation (times a week) (Supplementary Table 1). With regard to the number of people, we asked respondents "How many people were there within a 5-m radius of the scene?". Person risk represents the probability that a random person currently has COVID based on the overall prevalence in the person's area during each survey as well as recent behaviors of the person. Weighting coefficients were used for

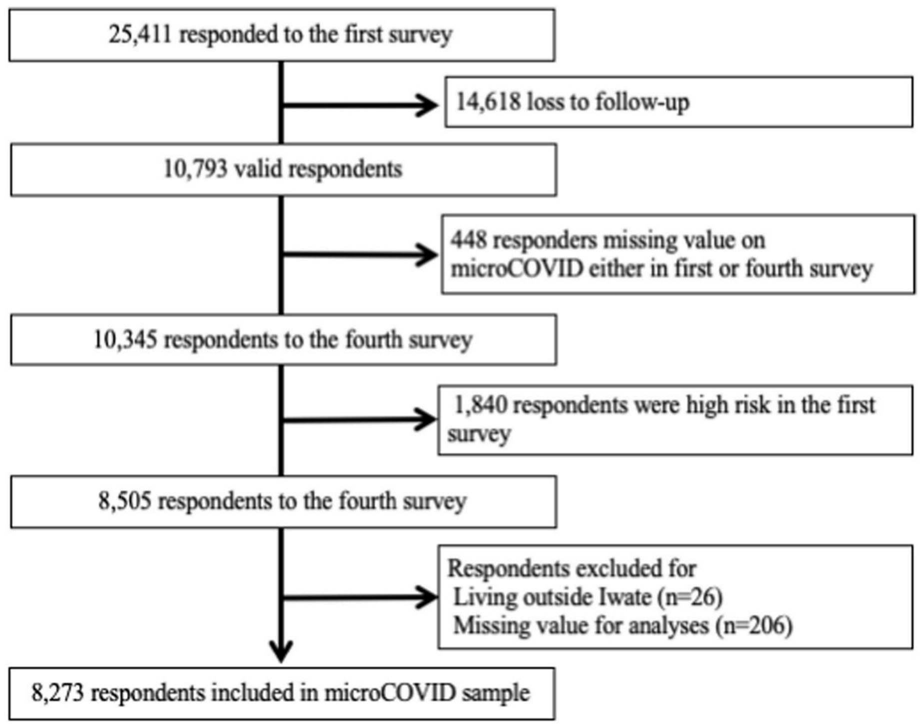

Fig. 1. Flow chart of the selection of respondents. Of 100,958 registered residents, 8273 residents were selected for this study.

the same values in both surveys and the risk scores for each individual were calculated in the first survey and in the fourth survey. We then classified each individual's risk level into low risk and high risk for infection (low-risk group, ≤20 microCOVIDs; high-risk group, >20 microCOVIDs).

2.4. Covariates

In the fourth survey, we assessed the respondents' level of knowledge regarding the COVID-19 vaccine. The questions included asking about: (1) the purpose of the vaccine, (2) who receives priority for receiving a vaccine, (3) the approved age for children to receive the vaccine, (4) persons who should not get the vaccine, (5) whether informed consent is needed, (6) whether there is a fee for the vaccine, (7) guarantee of safety, and (8) available medications for side effects. For each item, we asked the respondent whether they possessed knowledge about the topic (0 for "no", 1 for "yes"), and the responses were summed to obtain a total score (zero to eight). The participants were classified into four groups: very low level of vaccine knowledge (zero to three), low level of vaccine knowledge (four or five), moderate level of vaccine knowledge (six or seven), and high level of vaccine knowledge (eight). Cronbach's α of the scale was 0.810.

The first survey questionnaire also included questions about the respondent's age, sex, municipality of residence, occupation, number of household members living together, and the respondent's preventive practices. The participants were divided into three age categories: young (people under 40 years of age), middle age (people aged 40–59 years) and elderly (people aged 60 years or older). Residential areas were classified into inland versus coastal/mountainous based on the geography of Iwate Prefecture. Occupations were assessed by asking "What is your current job?". The participants were divided into five groups: health care workers, workers in service industries (e.g., transportation, customer-facing occupations in the retail/hospitality sector, office workers), education sector (teachers or students), government workers, and all others (workers in manufacturing, farmers/agricultural workers, workers in other jobs, or unemployed). The number of household members living together was divided into three groups: living alone, living with two to four persons, and living with five persons or more. With regard to respondent's preventive practices, we asked about 12 practices: wearing masks, hand washing and disinfecting with alcohol, cough etiquette, limiting social gatherings under the so-called "three Cs" (closed spaces, crowded places, and close-contact settings), regular self-management of health such as checking body temperature, frequent ventilation and controlling humidity, refraining from going out when not feeling well, gargling, registering contact information with apps or memos, avoiding conversations and vocalizations in "three Cs" situations, avoiding touching eyes, nose and mouth, and avoiding using the same items as those used by roommates. Each item was rated 0 (no) or 1 (yes) and the items were summed to obtain a total score (zero to twelve). The participants were classified into four groups: a poor level of measures (zero to three items), a low level of measures (four to six items), a middle level of measures (seven to nine items), and a high level of measures (ten to twelve items).

2.5. Statistical analyses

Baseline characteristics of participants in the low-risk group and high-risk group at the follow-up survey were compared by using the chi-squared test. Logistic regression analyses were conducted to determine the characteristics of participants whose behavior developed to high-risk behavior. Two models were used to identify trajectory predictors. In Model 1, we included explanatory variables of levels of vaccine knowledge, age groups, and sex. In Model 2, we additionally adjusted for residential areas, number of household members, and preventive measures in the first survey. Although no significant interactions were found between age groups and levels of vaccine knowledge (p for interaction, 0.740), we performed analyses stratified by age groups considering the difference in vaccination coverage rate according to age groups. For sensitivity analyses, we imputed missing covariate data by multiple imputation using the Markov Chain Monte Carlo method, creating five imputed datasets. We also show the odds ratios (ORs) of high risk of behavior according to level of vaccine knowledge which were converted from categorical variables into discrete variables (zero to eight). We used the Statistical Package for Social Sciences (SPSS) software program version 25.0 (IBM, Chicago, IL, USA) for all analyses. All statistical tests described were two-sided, and analysis items with P-values <0.05 were considered statistically significant.

3. Results

Table 1 compares the baseline characteristics of participants in the low-risk group versus high-risk group at the fourth survey. Contrary to our hypothesis (but in line with risk compensation theory), the proportion of participants with a high level of vaccine knowledge was *higher* in the high-risk group than in the low-risk group. There was no significant difference between the two groups in demographic characteristics or the proportion of participants who took preventive measures in the first survey (seven months earlier).

Table 2 shows the predictors of high-risk behavior in the two models. In model 1, individuals having a high level of vaccine knowledge had significantly higher OR. There was a dose-response association according to the four levels of vaccine knowledge, while engagement in preventive measures in the first survey was not associated with high-risk behavior in the follow-up survey. In model 2, while engagement in preventive measures did not have a significant association with high-risk behavior, the higher OR among individuals with a high level of vaccine knowledge remained significant after adjustment for relevant confounding factors (OR [95% confidence interval (CI)], 1.50 [1.17–1.93]; P = 0.001).

Stratified analyses by age groups showed that the OR in individuals with a high level of vaccine knowledge remained significantly higher for young and middle-aged people but disappeared in elderly people (Supplementary Table 2).

To consider possible selection bias caused by missing values, we calculated the ORs between people with missing values (Supplementary Table 3). The results were similar in the analyses with multiple imputation for missing data (n = 8,479). In the analyses for a discrete variable of vaccine knowledge (zero to eight), a dose response association between high-risk behavior and a high level of vaccine knowledge was observed (P for trend = 0.002). (Supplementary Table 4).

Table 1
Baseline characteristics of participants in the first survey (n = 8273).

		The fourth survey		
		Low-risk (n = 7,471)	High-risk (n = 802)	
		n (%)	n (%)	*P* value
Age groups	Young	1570 (21.0)	154 (19.2)	0.467
	Middle age	4555 (61.0)	497 (62.0)	
	Elderly	1346 (18.0)	151 (18.8)	
Sex	Women	5184 (69.4)	565 (70.4)	0.535
Area	Inland areas	6080 (81.4)	664 (82.8)	0.328
Occupation	Health care workers	1343 (18.0)	140 (17.5)	0.821
	Service	2191 (29.3)	251 (31.3)	
	Schools	519 (6.9)	52 (6.5)	
	Others	2651 (35.5)	281 (35.0)	
	Government workers	767 (10.3)	78 (9.7)	
Household members	Living alone	883 (11.8)	107 (13.3)	0.209
	Living with 2–4 persons	5397 (72.2)	556 (69.3)	
	Living with 5 persons or more	1191 (15.9)	139 (17.3)	
Levels of engagement of preventive measures	Poor	217 (2.9)	20 (2.5)	0.063
	Low	1583 (21.2)	147 (18.3)	
	Middle	3121 (41.8)	372 (46.4)	
	High	2550 (34.1)	263 (32.8)	
Levels of knowledge of vaccines	Very low	983 (13.2)	85 (10.6)	<0.001
	Low	1115 (14.9)	90 (11.2)	
	Moderate	2701 (36.2)	282 (35.2)	
	High	2672 (35.8)	345 (43.0)	

Categorical variables are presented as number of cases (%).
P values were calculated using the chi-squared test.

4. Discussion

We examined the transition to risky (transmission) behavior according to level of vaccine knowledge over a seven-month period (December 2020 to July 2021) when vaccines became widely available in Japan. Contrary to our hypothesis, people with a high level of knowledge about the vaccine had significantly higher ORs of transitioning to high-risk behavior compared to people with a low level of vaccine knowledge. There has been no study in which the association between levels of vaccine knowledge and preventive behaviors was examined in a longitudinal survey.

Most previous studies focused on the association between knowledge levels and/or positive perception of vaccines in relation to vaccine intentions versus vaccine hesitancy (Dubé et al., 2013; WHO Technical advisory group on behavioral insights and sciences for health, 2020; Li et al., 2020; Milošević Đorđević et al., 2021; Prasetyo et al., 2020). Few studies have focused on the association between levels of vaccine knowledge and preventive behaviors.

Based on Protection Motivation Theory, Chen et al. examined whether knowledge regarding COVID-19 vaccines was positively associated with the motivation to get vaccinated and to adopt preventive behaviors against COVID-19 in an online survey from October 2020 to December 2020 in Taiwan (n = 1,047) (Chen et al., 2021). Participants in that study with low levels of motivation for getting vaccinated or adopting preventive behaviors had a lower level of knowledge of COVID-19 vaccination (i.e., the opposite of what we found). Motoki et al. examined whether scientific literacy regarding COVID-19 was associated with attitudes toward COVID-19 vaccinations and preventive behaviors in an online survey conducted in April 2021 in Japan (n = 500) (Motoki et al., 2021). Scientific literacy regarding the vaccine had a weak negative correlation with preventive behavior, i.e., their results were consistent with our results.

These two previous studies differed from our study in terms of the timing when the surveys were conducted: the study by Chen et al. was conducted from October 2020 to December 2020, when no vaccine was available in Taiwan, while the study by Motoki et al. was conducted in April 2021, when vaccinations in Japan were limited to health care workers. Our study was conducted in July 2021, when health care workers as well as people aged 65 years or older could receive vaccines. Moreover, while participants in the two previous studies were asked only a few questions about adopting preventive behaviors, our study used a more comprehensive assessment tool to capture the behavior of participants in our study.

Although we could not determine the precise reasons for the inverse association between high level of vaccine knowledge and the practice of COVID-19 preventive behaviors, there are some possible explanations. According to risk compensation theory, some individuals have a tendency to adjust their behavior in response to changes in the perceived level of risk – taking more risks if they feel protected (Sandroni and Squintani, 2004). For example, some studies have suggested that vaccinated respondents were less likely to continue to adopt preventive

Table 2
Results of analysis using models for risk trajectories (n = 8,273).

		Model 1		Model 2	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Levels of knowledge of vaccines	Low (ref: very low)	0.93 (0.68–1.27)	0.644	0.93 (0.69–1.27)	0.665
	Moderate	1.20 (0.94–1.55)	0.15	1.21 (0.94–1.56)	0.138
	High	1.49 (1.16–1.91)	0.002	1.50 (1.17–1.93)	0.001
Age groups	Young (ref: elderly)	0.87 (0.68–1.10)	0.239	0.86 (0.67–1.11)	0.243
	Middle age	0.97 (0.80–1.18)	0.743	0.96 (0.78–1.17)	0.668
Sex	Women (ref: men)	1.06 (0.90–1.25)	0.463	1.06 (0.89–1.25)	0.524
Area	Inland areas (ref: coastal and mountainous areas)			1.10 (0.90–1.33)	0.359
Occupation	Health care workers (ref: government workers)			1.02 (0.75–1.36)	0.924
	Service			1.13 (0.86–1.48)	0.39
	Schools			1.00 (0.69–1.44)	0.978
	Others			1.02 (0.78–1.34)	0.867
The number of households	Living alone (ref: living with 5 persons or more)			1.03 (0.78–1.34)	0.858
	Living with 2–4 persons			0.86 (0.71–1.05)	0.147
Levels of engagement of preventive measures	Moderate (ref: high)			1.16 (0.98–1.37)	0.631
	Low			0.91 (0.73–1.13)	0.268
	Poor			0.89 (0.55–1.44)	0.929

Abbreviations: CI, confidence interval; OR, odds ratio.

behaviors against HIV or human papillomavirus (Brewer et al., 2007; Newman et al., 2010). In the case of COVID-19, Paez showed comparison of analyses about the association between reproductive rate and density by using some data and their team also showed the incidence of COVID-19 was lower in high population density across the lockdown in 2020 in Spain (Paez et al., 2021Paez, 2021). Some people might have let their guard down and stopped practicing strict preventive behaviors when they learned about the availability of a vaccine, i.e., people might have come to view vaccination as signifying the end of the pandemic (Natalie, 2021). Such individuals might have stopped practicing protective behaviors due to their optimism for a return to normalcy. Lai et al. showed that higher optimism scores for avoiding infection were significantly associated with a lower level of intention to take preventive action in the hypothetical situation of a flu outbreak (Lai et al., 2000). In Japan, since vaccine priority was assigned to individuals aged 65 years and older or health care workers, only 11% of the total population had been vaccinated with a second dose of a vaccine by June 2021. On the other hand, even though most people were not yet vaccinated, they might have developed a case of over-confidence based on scientific evidence about the efficacy of vaccination against SARS-CoV-2 infection.

Stratified analyses showed that ORs of high-risk behavior were significantly higher in young and middle-aged people with a high level of knowledge about the COVID-19 vaccine. While the OR tended to be also elevated in elderly people with a high level of knowledge, the association was not statistically significant in this group. At the end of June in 2021, the vaccination rates were 1.5% in people 64 years of age or younger and 35.8% in people 65 years of age or older in Japan (Government CIOs' Portal, 2021). Interestingly, people with a high level of vaccine knowledge had a significantly higher behavioral risk in the non-eligible age groups for a vaccine (young and middle age groups), and young people with a high level of vaccine knowledge showed higher ORs of risky behavior for COVID-19 than in the middle-aged and elderly groups. Even though they had not received vaccines, younger people might be more susceptible to over-confidence upon receiving information about the efficacy of the COVID-19 vaccine. Previous studies showed that preventive behaviors were significantly less prevalent in younger age group compared to other age groups, possibly reflecting the less serious consequences of infection in this age group, i.e., risks of hospitalization and death (An et al., 2020; X. Chen and Chen, 2020).

4.1. Limitations

The present study had several limitations. First, the participants were not asked questions about educational attainment, job titles, occupational classes, and household income. Also, respondents already vaccinated were not determined in our survey and questions relevant to decision-making around vaccination were not asked (such as perceived risk), but we know that only an estimated 11.2% of eligible people in Iwate were vaccinated at the time of the surveys. Second, the possibility of selection bias should be considered since the participants were limited to registered respondents in online health surveys conducted by the Iwate Prefectural Government. We conducted a comparison of characteristics of the participants in the first survey (December 2020) with characteristics of the whole population in Iwate in 2021 (Supplementary Table 5). The percentages of young and older people and the percentage of men were higher in the Census data than in our study. There was a higher proportion of middle-aged women living in inland areas in our study.

5. Conclusion

People with a high level of vaccine knowledge were found to adopt higher behavioral risks for infection over a seven-month period. Our results indicate the importance of taking additional measures (such as education) to prevent the relaxation of preventive behaviors for COVID-19 due to overconfidence and risk compensation. Since new variants of SARS-CoV-2 have evolved, policy makers should continue to communicate strong messages to keep a high level of consciousness and maintain basic preventive measures even after widespread vaccination.

Credit Author Statement

S Takahashi: funding acquisition, conceptualization, formal analysis and writing – original draft. S Yamada: verified the underlying data, data curation, resources and writing – review & editing. S Sasaki: investigation, project administration and writing – review & editing. N Takahashi: investigation and writing – review & editing. M Nohara: project administration, resources, supervision and writing – review & editing. I Kawachi: methodology, supervision, validation and writing – review & editing.

Declaration of competing interest

All authors have no conflicts of interest to disclose.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

An, L., Hawley, S., Van Horn, M.L., Bacon, E., Yang, P., Resnicow, K., 2020. Development of a coronavirus social distance attitudes scale. Patient Educ. Counsel.

Brewer, N.T., Cuite, C.L., Herrington, J.E., Weinstein, N.D., 2007. Risk compensation and vaccination: can getting vaccinated cause people to engage in risky behaviors? Ann. Behav. Med. 34, 95–99.

Centers for Disease Control and Prevention, 2021a. COVID-19 Vaccine Effectiveness. The United States: Centers for Disease Control and Prevention. Aug 28, 2021. https://www.cdc.gov/coronavirus/2019-ncov/vaccines/effectiveness/how-they-work.html.

Centers for Disease Control and Prevention, 2021b. SARS-CoV-2 Variant Classifications and Definitions. The United States: Centers for Disease Control and Prevention. Aug 24, 2021. https://www.cdc.gov/coronavirus/2019-ncov/variants/variant-info.html.

Chen, X., Chen, H., 2020. Differences in preventive behaviors of COVID-19 between urban and rural residents: lessons learned from A cross-sectional study in China. Int. J. Environ. Res. Publ. Health 17.

Chen, Y.L., Lin, Y.J., Chang, Y.P., Chou, W.J., Yen, C.F., 2021. Differences in the protection motivation theory constructs between people with various latent classes of motivation for vaccination and preventive behaviors against COVID-19 in Taiwan. Int. J. Environ. Res. Publ. Health 18.

Dubé, E., Laberge, C., Guay, M., Bramadat, P., Roy, R., Bettinger, J., 2013. Vaccine hesitancy: an overview. Hum. Vaccines Immunother. 9, 1763–1773.

Glanz, K., Rimer, B.K., Viswanath, K., 2008. Health Behavior and Health Education: Theory, Research, and Practice, fourth ed. Jossey-Bass, San Francisco, CA, US.

Gordon, A., Reich, M.R., 2021. The puzzle of vaccine hesitancy in Japan. J. Jpn. Stud. 47, 411–436.

Government CIOs' Portal, Japan, 2021. Vaccination Status of Novel Cornavirus Vaccine. Information Related to Novel Cornavirus Infection "COVID-19. Government CIOs' Portal, Japan, Tokyo. Oct 9, 2021. https://cio.go.jp/vrs.

Iwate Prefectural Government, 2021. Information on Confirmed Cases in Iwate. Iwate Prefecture. Iwate Prefectural Government. https://www.pref.iwate.jp/kurashikankyou/iryou/covid19/index.html. (Accessed 13 August 2021).

Johns Hopkins University and Medicine, 2021a. COVID-19 Data in Motion: Monday, November 11, 2021. Johns Hopkins University and Medicine, USA. Nov 11, 2021. https://coronavirus.jhu.edu/.

Johns Hopkins University and Medicine, 2021b. Understanding Vaccination Progress. Johns Hopkins University and Medicine, USA. Nov 11, 2021. https://coronavirus.jhu.edu/vaccines/international.

Lai, J.C., Hamid, P.N., Cheng, S.T., 2000. Health beliefs and optimism as predictors of preventive health decisions in Hong Kong Chinese. Psychol. Rep. 86, 1059–1070.

Li, S., Feng, B., Liao, W., Pan, W., 2020. Internet use, risk awareness, and demographic characteristics associated with engagement in preventive behaviors and testing: cross-sectional survey on COVID-19 in the United States. J. Med. Internet Res. 22, e19782.

Milošević Đorđević, J., Mari, S., Vdović, M., Milošević, A., 2021. Links between conspiracy beliefs, vaccine knowledge, and trust: anti-vaccine behavior of Serbian adults. Soc. Sci. Med. 277, 113930.

Ministry of Health, Labour and Welfare, 2021. Situation Update for COVID-19 and the MHLW's Response (Nov. 11, 2021). Ministry of Health,Labour and Welfare, Tokyo. Accessed date: Nov 11, 2021. https://www.mhlw.go.jp/stf/covid-19/kokunainohasseijoukyou.html.

Moore, J.P., Offit, P.A., 2021. SARS-CoV-2 vaccines and the growing threat of viral variants. JAMA 325, 821–822.

Motoki, K., Saito, T., Takano, Y., 2021. Scientific literacy linked to attitudes toward COVID-19 vaccinations: a pre-registered study. Front. Commun. 6.

Natalie, T., 2021. The Vaccine Optimism Effect: Why Vaccine News Might Reduce Social Distancing. AUG 27, 2021. https://thedecisionlab.com/insights/health/the-vaccine-optimism-effect-why-vaccine-news-might-reduce-social-distancing/.

Newman, P.A., Roungprakhon, S., Tepjan, S., Yim, S., 2010. Preventive HIV vaccine acceptability and behavioral risk compensation among high-risk men who have sex with men and transgenders in Thailand. Vaccine 28, 958–964.

Paez, A., Lopez, F.A., Menezes, T., Cavalcanti, R., Pitta, M.G.d.R., 2021. A spatio-Temporal analysis of the environmental correlates of COVID-19 incidence in Spain. Geogr. Anal. 53, 397–421.

Prasetyo, Y.T., Castillo, A.M., Salonga, L.J., Sia, J.A., Seneta, J.A., 2020. Factors affecting perceived effectiveness of COVID-19 prevention measures among Filipinos during enhanced community quarantine in Luzon, Philippines: integrating protection motivation theory and extended theory of planned behavior. Int. J. Infect. Dis. 99, 312–323.

Sandroni, A., Squintani, F., 2004. A Survey on Overconfidence, Insurance and Self-Assessment Training Programs. June 23, 2022. https://warwick.ac.uk/fac/soc/economics/staff/fsquintani/research/survey_overconfidence.pdf.

Shahnazi, H., Ahmadi-Livani, M., Pahlavanzadeh, B., Rajabi, A., Hamrah, M.S., Charkazi, A., 2020. Assessing preventive health behaviors from COVID-19: a cross sectional study with health belief model in Golestan Province, Northern of Iran. Infect. Dis. Poverty 9, 157.

The microCOVID Project, 2020. microCOVID Project. San Francisco Nov 27, 2020. https://www.microcovid.org.

WHO Technical advisory group on behavioral insights and sciences for health, 2020. Acceptance and Uptake of COVID-19 Vaccines. Geneva Oct 15, 2021. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjVmJPIrKPzAhWXPXAKHTYIBvAQFnoECAQQAQ&url=https%3A%2F%2Fapps.who.int%2Firis%2Frest%2Fbitstreams%2F1320080%2Fretrieve&usg=AOvVaw3YXQzfU3dr_7_A9OSiiwhy.

World Health Organization, 2021. COVID-19 Vaccine. World Health Organization. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines. (Accessed 27 August 2021).

Paez, A. Reproducibility of research during COVID-19: examining the case of population density and the basic reproductive rate from the perspective of spatial analysis. Geogr. Anal. 2021 Nov 18;10.1111/gean.12307.