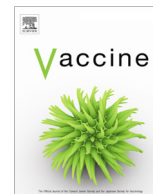




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COVID-19 vaccine literacy and vaccine hesitancy among pregnant women and mothers of young children in Japan



Yoko Takahashi^{a,b}, Kazue Ishitsuka^{a,*}, Makiko Sampei^{a,c}, Sumiyo Okawa^d, Yoshihiko Hosokawa^e, Akira Ishiguro^b, Takahiro Tabuchi^f, Naho Morisaki^a

^a Department of Social Medicine, National Center for Child Health and Development, 2-10-1 Okura Segataya-ku Tokyo, Japan

^b Center for Postgraduate Education and Training, National Center for Child Health and Development, 2-10-1 Okura Segataya-ku, Tokyo, Japan

^c Department of Nursing and Social Epidemiology, Nippon Sport Science University, 7-1-1, Fukasawa, Setagaya-ku, Tokyo, Japan

^d Institute for Global Health Policy Research, Bureau of International Health Cooperation, National Center for Global Health and Medicine, 1-21-1, Toyama, Shinjuku-ku, Tokyo, Japan

^e Department of Obstetrics and Gynecology, Faculty of Medicine, University of Tsukuba, Ibaraki, 1-1-1 Ten-no-dai, Tsukuba, Ibaraki, Japan

^f Cancer Control Center, Osaka International Cancer Institute, 3-1-69 Otemae, Chuo-ku, Osaka, Osaka, Japan

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ABSTRACT

Background: Delays in the spread of vaccination have been recognized as an urgent public health issue in the context of the COVID-19 pandemic. Vaccine literacy (VL) is a critical determinant of vaccine uptake; however, little is known about VL among pregnant women and mothers of young children.

Methods: We analyzed data from a nationwide, cross-sectional internet survey in Japan on VL and vaccine hesitancy, conducted with 1,639 pregnant women and 5,688 mothers of young children who had given birth after July 2019, between July 24 and August 30, 2021.

Results: Vaccine hesitancy was observed in 51.1 % of pregnant women and 31.9 % of mothers of young children. The risk of vaccine hesitancy was significantly higher among pregnant women with lower interactive/critical skills (risk ratio [RR] 2.10, 95 % confidence interval [CI] 1.59, 2.78, $p < 0.001$), although functional skills did not significantly correlate with vaccine hesitancy. For mothers of young children, we found a significantly higher risk of vaccine hesitancy among those with low VL functional skills (RR 1.38, 95 % CI 1.19, 1.61), $p < 0.001$) and low interactive/critical skills (RR 1.29, 95 % CI 1.10, 1.50, $p = 0.001$).

Conclusions: Our findings suggest that aiding individuals to correctly evaluate vaccine-related information is critical for improving vaccine acceptance rates among both pregnant women and mothers of young children. Meanwhile, improving the comprehensibility of communication toolkits may be important for women with children but have a limited effect among pregnant women.

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1. Introduction

The novel coronavirus disease-19 (COVID-19) was declared a pandemic by the World Health Organization (WHO) in March 2020 and has since affected hundreds of millions of people worldwide[1]. Pregnant women are known to be at increased risk for developing severe maternal and fetal sequelae of COVID-19 involving increased maternal admission to intensive care units, need for mechanical ventilation, mortality, and preterm births[2,3]. To date, vaccination appears to be the most effective strategy to control this

widespread pandemic, and many countries gave top priority to mass vaccine distribution once supplies of COVID-19 vaccines became available. The COVID-19 vaccines are highly effective in preventing onset, infection, and severe illness among all population types including pregnant and lactating women. The American College of Obstetricians and Gynecologists (ACOG) strongly recommends that all people planning pregnancy or those who are pregnant or who have been recently pregnant undergo COVID-19 vaccination[4]. Vaccination acceptance is important because high vaccination rates of up to 75–90 % are needed to achieve sufficient herd immunity [5,6].

In Japan, a national vaccine program was developed in February 2021, first targeting medical care workers and people over 65 years; then, it was extended to all those aged under 65 years of age in May 2021[7]. Vaccines have been available for free to

Abbreviations: VL, vaccine literacy.

* Corresponding author at: Department of Social Medicine, National Center for Child Health and Development, 2-10-1 Okura Segataya-ku, Tokyo, Japan.

E-mail address: ishitsuka-k@ncchd.go.jp (K. Ishitsuka).

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every-one over 18 years old since June 2021[7]. The Japan Society of Obstetrics and Gynecology initially recommended vaccination of pregnant women after 12 weeks of gestation in January 2021[8]. However, based on data showing vaccine safety and efficacy, the government recommended vaccination for all pregnant women in August 2021[9]. Vaccine hesitancy, defined as a “delay in acceptance or refusal of vaccination despite availability of vaccination services”[10], has been recognized as a major threat to the WHO’s public health strategy as it could limit or delay the spread of COVID-19 vaccination [11]. In addition to those who adamantly refuse vaccination, those who wish to postpone their decision are also considered to be vaccine hesitant, enhancing the importance of this issue. Previous studies of pregnant and young women have shown that they have very low vaccination intentions compared with other groups, which suggests that vaccine hesitancy is more prevalent among this population worldwide [12,13]. During the COVID-19 pandemic in Japan, parents of young children, especially those with infants, refrained from visiting hospitals to avoid the risk of infection, which affected immunization rates [14,15]. Improving vaccine intention among pregnant and lactating women as well as among mothers of young children would be of major benefit to public health.

“Vaccine literacy” (VL) is a critical determinant of vaccine uptake [16,17]. VL is defined as “not simply knowledge about vaccines, but also developing a system with decreased complexity to communicate and offer vaccines as sine qua non of a functioning health system” [16]. The concept of VL has been built upon the same characteristics as those of health literacy [18,19], that is, the cognitive and social skills that directly affect an individual’s ability to access and understand health information efficiently and make appropriate decisions [20]. The COVID-19 Vaccine Literacy Scale was created by Biasio et al. based on the three components of health literacy proposed by Ishikawa et al.: 1) functional skills, that is, the basic reading and writing skills that are necessary to function effectively in everyday situations, including the comprehension of health information; 2) interactive skills, that is, the more advanced cognitive and literacy skills that, together with communicative literacy, can be used to actively participate in everyday situations, extract information, and derive meaning from different forms of communication and apply this to changing circumstances; and 3) critical skills, that is, the highest level of cognitive and social skills, which can be applied to critically analyze information and subsequently exert greater control over life events and situations [20,21]. Higher functional and interactive/critical skills have been reported to be related to higher COVID-19 vaccine acceptance [22,23], suggesting that not only providing information about vaccines but also improving levels of cognitive and social literacy are essential for improving vaccine acceptance among the global population [18].

COVID-19 VL likely differs from VL for other diseases since the frequent updates on what is known require individuals to collect and interpret information at a much faster pace. Though COVID-19 VL has been studied among the general population [22,23], little is known about VL among pregnant women and those with young children, even though pregnant women are at higher risk of severe illness from symptomatic COVID-19 [2] and vaccinating parents is essential to protect young children who are not eligible to be vaccinated themselves. Understanding how COVID-19 VL relates to vaccine acceptance among pregnant women, as well as the factors associated with VL, is crucial for developing tailored strategies to address vaccine hesitancy. Furthermore, evaluating the situation among mothers of young children to see whether there are differences between the two populations is also likely to be useful. Thus, this study aimed to evaluate whether VL is correlated with vaccine acceptance among pregnant women and mothers of young children and identify the factors associated with COVID-19 vaccine

hesitancy and VL in Japan. As these groups are known to be more likely to be vaccine hesitant both in Japan and in other countries, it is expected that this study’s findings may provide useful guidance on improving their vaccine acceptance.

2. Materials and Methods

2.1. Study design and participants

We analyzed data from a cross-sectional, population-based, internet questionnaire conducted as part of the Japan COVID-19 and Society Internet Survey (JACSIS). Details of the JACSIS are described in our previous study [24]. The survey was conducted between July 24 and August 30, 2021, based on the recruitment of 14,080 women who were pregnant and expected to give birth by December 2021 or who had given birth after July 2019 and 3,434 of their partners, who had signed up to be included in the online panel. Answers were collected from the first 10,000 responders, including 8,047 women and 1,953 partners. A total of 7,327 (1639 pregnant women (22.4 %), and 5,688 mothers of young children under 2 years (77.6 %)) were included in the analysis, following the exclusion of 720 women who provided irrelevant or contradictory information. Participants were informed of the nature of the study and provided web-based informed consent before responding to the questionnaire. They could cease participation in the survey at any point.

The infection and vaccination status in Japan during the study period were shown in our previous study [9]. An explosive spread of the COVID-19 pandemic occurred nationwide, mainly in terms of the Delta variant. Consequently, the cumulative number of infected people increased from 892,753 on July 28 to 1,476,805 on August 30 [7]. The government promoted vaccination opportunities to all those over 12 years old throughout the country, with the vaccine coverage rate reaching 70 % and 38.6 % among older adults and the total population who had received a first dose, respectively.

3. COVID-19 vaccine hesitancy

The survey asked the participants, “What do you think about COVID-19 vaccination?” The respondents answered by selecting one of the following options: “I have already been vaccinated,” “I want to be vaccinated,” “I want to ‘wait and see’ before getting the vaccine,” and “I do not want to be vaccinated.” Based on the definition of vaccine hesitancy and a previous review [10,25], “vaccine-acceptant” respondents were defined as those who chose the answers, “I have already been vaccinated” and “I want to be vaccinated,” while those who answered “I want to ‘wait and see’ before getting the vaccine,” and “I do not want to be vaccinated” were defined as “vaccine hesitant.”

The survey then asked the vaccine-acceptance group about their reasons for getting vaccinated against COVID-19 and asked the vaccine-hesitant group about their reasons for not getting vaccinated. Multiple answers were allowed; therefore, the sum of the proportions for each reason did not necessarily total 100 %.

4. Vaccine literacy

VL levels were assessed using the COVID-19 VL scales reported by Biasio et al., adapting 12 questions from a self-reported questionnaire on adult vaccination[26]. Four items of the questionnaire assess functional VL, and eight items evaluate interactive-critical VL. Each response is given on a 4-point Likert scale (ranging from 1 = never to 4 = often, and in reversed items, from 1 = often to 4 = never). The scores were obtained from the mean value of the

answers in each scale (range, 1–4), with a higher value corresponding to a higher VL level [22,26]. This scale was built based on the health literacy scale, including its three health literacy types, proposed by Ishikawa for use among patients with chronic non-communicable diseases [27]. This instrument has been already validated, and its correlation with COVID-19 vaccination has been assessed in online surveys in Italy and Croatia [22,23].

We used a Japanese version, which was translated after obtaining permission from the authors of the original scale, and we divided functional and interactive/critical VL scores into “low” “medium” and “high” literacy levels using the tertiles of each score. The responses to the questions related to functional and interactive/critical literacy showed good internal consistency, resulting in a Cronbach’s alpha of 0.82 for the whole questionnaire. Principal component analysis (PCA) with varimax rotation was conducted to investigate how the questions in the functional and interactive-critical scales were related to one another and to assess whether the underlying components (factors) and each question’s load on the components could be identified as anticipated (Table 1). All functional literacy questions loaded on the first component, while all interactive/critical questions loaded on the second component.

5. Information resources, health literacy, and healthy habits

Participants were asked, “Where do you obtain reliable information about COVID-19?”, with multiple response options allowed from the following selection: (i) Family, friends, and colleagues; (ii) medical doctors; (iii) experts; (iv) official government and academic websites; (v) social media, including YouTube, LINE, Twitter, Facebook, and Instagram; (vi) newspapers, books, and magazines; (vii) television and radio; (ix) internet news; and (x) celebrities.

We assessed health literacy using the Communicative and Critical Health Literacy (CCHL) scale [28]. This scale was developed to easily evaluate interactive and critical health literacy skills via five

Table 1
Factor-loading matrix using principal component analysis.

Question*	Factor 1	Factor 2
1) Functional VL		
When reading or listening to information about future COVID-19 vaccines or current vaccines:		
No. 1 Did you find words you didn’t know?	0.05	0.79
No. 2 Did you find that the texts were difficult to understand?	0.02	0.89
No. 3 Did you need much time to understand them?	0.00	0.86
No. 4 Did you or would you need someone to help you understand them?	−0.01	0.65
2) Interactive/critical VL		
When looking for information about future COVID-19 vaccines or current vaccines:		
No. 5 Have you consulted more than one source of information?	0.67	0.10
No. 6 Did you find the information you were looking for?	0.70	−0.02
No. 7 Have you had the opportunity to use the information?	0.68	0.02
No. 8 Did you discuss what you understood about vaccinations with your doctor or other people?	0.50	0.04
No. 9 Did you consider whether the information collected was about your condition?	0.75	0.03
No. 10 Have you consider the credibility of the sources?	0.74	0.02
No. 11 Did you check whether the information was correct?	0.70	0.01
No. 12 Did you find any useful information to make a decision on whether or not to get vaccinated?	0.78	−0.01

VL, vaccine literacy.

*Functional VL questions 1–4 and interactive-critical VL questions 5–12 loading on two different components (Factor 1 and Factor 2).

questions [28] and has been used in the general population, as well as among those with chronic diseases.

We also asked participants about their infection prevention practices and healthy daily habits. Infection prevention practices were assessed using 14 questions on the frequency of performing nine different preventive measures (social distancing, wearing masks, avoiding closed spaces, avoiding crowded spaces, avoiding close contact settings, hand washing, avoiding touching one’s face, respiratory hygiene, and surface disinfection) on a 4-point Likert scale (always, sometimes, almost never, and never). We calculated the mean value of the answers to each scale (range, 1–4) and created a composite score for the infection prevention practices the respondents carried out. To evaluate the respondents’ healthy daily habits, three questions were asked about the frequency of eating a well-balanced diet, eating breakfast, and regulating their daily lives on a 4-point Likert scale (always, sometimes, almost never, never). We calculated the mean value of the three answers as a composite score for healthy daily habits.

6. Covariates

Respondents answered questions on their demographics, including their age, whether they were pregnant/had given birth, and their household income, occupation, and educational attainment level. We calculated household income as the total annual income of all household members and categorized it as follows: (i) < 2 million Japanese yen (JPY), (ii) between 2 and 4 million JPY, (iii) between 4 and 6 million JPY, (iv) between 6 and 8 million JPY, (v) between 8 and 10 million JPY, and (vi) over 10 million JPY. Educational attainment was measured through a multiple-choice question with the following possible responses: (i) junior high school, (ii) high school, (iii) vocational education, (iv) junior college, (v) university, and (vi) graduate school.

6.1. Statistical analysis

Data were analyzed using Stata version 16.1 (StataCorp LP, College Station, TX, USA). Descriptive statistics were calculated for all variables to summarize the respondents’ characteristics and the measured variables. Categorical and continuous variables were expressed as means and standard deviation (SD) or 95 % confidence intervals (CI). The χ^2 test was used to compare categorical data.

Since the outcome was more than 10 %, Poisson regression analyses were used [29] to estimate the risk ratios (RR) and 95 % CI of the proportions of COVID-19 vaccine hesitancy by the functional VL and interactive/critical VL levels of the pregnant women and mothers of young children, adjusted for age, education, household income, and health literacy score. We also performed difference-in-difference analysis to compare the association between VL components and being pregnant or not. Two-sided p-values below 0.05 were considered statistically significant.

Ethical considerations

All procedures were conducted following the ethical standards stipulated in the 2013 revision of the Helsinki Declaration of 1975. The Research Ethics Committee of the Osaka International Cancer Institute reviewed the study protocol and gave ethical approval. The internet survey agency protected personal information by strictly following the Act on the Protection of Personal Information in Japan. A web-based informed consent form was signed by respondents before proceeding to the online questionnaire. Credit points (‘Epoints’), which can be used in online stores or converted to cash, were offered as incentives.

7. Results

A total of 7,327 women consented and responded to the survey, including 1,639 pregnant women (22.4 %) and 5,688 mothers of young children (77.6 %). Their characteristics and socioeconomic demographics are listed in **Table 2 and Supplemental Table 1**. The survey revealed that 51.1 % of the pregnant women and 31.9 % of the mothers of young children were vaccine hesitant, respectively (answering, “I want to wait and see” or “do not want to be vaccinated”). A total of 42.8 % of the pregnant women and 26.1 % of the mothers of young children answered, “I want to wait and see before getting the vaccine,” and 8.3 % of the pregnant women and 5.8 % of the mothers of young children answered, “I do not want to be vaccinated.” The mean score of functional VL skills was 2.62 ± 0.75 for the pregnant women and 2.62 ± 0.77 for the mothers of young children, while the interactive/critical VL skills scores were 2.76 ± 0.61 for the pregnant women and 2.69 ± 0.62 for the mothers of young children, out of a maximum of 4.

Among both the pregnant women and the mothers of young children, a higher proportion of women with lower education levels and lower household income, and a lower proportion of women in full-time employment, were found in the groups with high vaccine acceptance. For the mothers of young children, the percentage of housewives/unemployed was higher in the vaccine-hesitant groups. The respondents’ infection prevention practices were similar across all four groups, with slightly lower

average scores among the mothers of young children who responded, “I do not want to be vaccinated” and higher scores among the pregnant women who responded, “I want to be vaccinated.” The mean score for health literacy was similar among the pregnant women (3.55 ± 0.68) and the mothers of young children (3.53 ± 0.72). In both groups, the average health literacy score was lower among the groups with lower vaccine acceptance.

The results of the fully adjusted regression analyses showed that lower functional VL skills did not correspond with significantly higher odds of vaccine hesitancy among the pregnant women. In contrast, low and medium-level interactive/critical VL skills significantly increased the risk of vaccine hesitancy (medium level RR 1.60, 95 % CI 1.19, 2.17, *p* = 0.002; low level RR 1.69, 95 % CI 1.23, 2.31; *p* < 0.001). Among the women with young children, a significantly higher risk of vaccine hesitancy was observed for those with low functional VL skills (RR 1.37, 95 % CI 1.18, 1.60; *p* < 0.001) and low interactive/critical literacy (RR 1.28, 95 % CI 1.10, 1.49; *p* = 0.002) in difference-in-difference analysis (**Table 3**). Similar results were seen in multivariate Poisson regression analysis within each group (**Supplemental Table 2**).

As the functional and interactive/critical VL skills had different impacts on vaccine hesitancy in the two populations, we further examined the reasons the women in each group listed for preferring not to get vaccinated. **Table 4** shows the proportions of women who were vaccine-hesitant and lists each reason by functional VL skill level and interactive/critical skill level of the pregnant women and the mothers of young children. The most common reason for

Table 2
Demographics of the participants included in the analysis.

	Pregnant women				Mothers of young children			
	Vaccine acceptance		Vaccine hesitancy		Vaccine acceptance		Vaccine hesitancy	
	Already Vaccinated (n = 218)	Want to get vaccinated (n = 583)	Want to “wait and see” (n = 702)	Don’t want to get vaccinated (n = 136)	Already Vaccinated (n = 1498)	Want to get vaccinated (n = 2371)	Want to “wait and see” (n = 1487)	Don’t want to get vaccinated (n = 332)
Age (mean [SD])	31.8(4.0)	31.7(4.4)	31.4(4.7)	31.0(4.4)	32.5(4.3)	32.4(4.3)	31.6(4.5)	31.8(4.5)
Education (n [%])								
Junior high school graduate	3(1.38)	1(0.2)	7(1)	0(0)	1(0.07)	9(0.38)	14(1)	6(1.81)
High school	14(6.4)	82(14)	121(17.4)	23(16.9)	140(9.4)	331(14)	327(22.1)	78(23.5)
Vocational school graduate	36(16.5)	91(15.6)	129(18.5)	34(25)	306(21)	448(19)	280(18.9)	72(21.7)
Two-year college graduate	19(8.7)	61(10.5)	85(12.2)	13(9.6)	155(10.4)	305(12.9)	189(12.8)	43(13)
Bachelor’s degree	135(61.9)	325(55.8)	344(49.4)	60(44.1)	827(55.4)	201(50.8)	637(43)	127(38.3)
Master’s or doctoral degree	11(5.1)	23(4)	11(1.6)	6(4.4)	64(4.3)	71(3)	33(2.2)	6(1.8)
Job (n [%])								
Officer	9(4.6)	6(1.3)	12(2.2)	5(4.9)	40(3.1)	50(2.72)	36(3.2)	9(3.5)
Self-employed	4(2.1)	15(3.2)	12(2.2)	3(3)	22(1.7)	49(2.7)	35(3.1)	13(5.1)
Full-time employment	128(65.6)	269(58.1)	290(53.9)	54(52.9)	885(68.0)	1033(56.1)	566(49.5)	108(42)
Temporary worker	4(2.1)	18(3.9)	10(1.9)	1(0.98)	21(1.6)	42(2.3)	29(2.5)	5(2)
Part-time employment	41(21)	93(20.1)	138(25.7)	21(20.6)	211(16.2)	328(17.8)	255(22.3)	61(23.9)
Student	0(0)	0(0)	1(0.19)	0(0)	0(0)	0(0)	0(0)	2(0.8)
Housewife/ unemployed	9(4.6)	62(14)	73(13.6)	16(15.7)	119(9.2)	331(18)	217(19)	58(22.7)
Other	0(0)	0(0)	2(0.4)	2(2)	3(0.23)	7(0.38)	5(0.44)	0(0)
Household income (YEN) (n [%])								
< 2million	3(1.4)	8(1.4)	14(2)	5(3.7)	10(0.7)	18(0.8)	24(1.6)	9(2.7)
2–4 million	6(2.8)	21(3.6)	31(4.4)	6(4.4)	47(3.1)	134(5.7)	130(8.7)	30(9)
4–6 million	21(9.6)	110(18.9)	121(17.2)	23(16.9)	193(12.9)	470(19.8)	315(21.8)	68(20.5)
6–8 million	36(16.5)	117(20.1)	147(20.9)	27(19.9)	317(21.2)	546(23)	283(19)	65(19.6)
8–10 million	40(18.4)	109(18.7)	111(15.8)	19(14)	289(19.3)	333(14.0)	196(13.2)	35(10.6)
greater than10 million	112(18.4)	218(37.4)	278(39.6)	56(41.2)	642(42.9)	870(36.7)	539(36.3)	125(37.7)
Infection prevention practices (n [%])								
Healthy daily habits (n [%])	3.52(0.51)	3.47(0.55)	3.45(0.56)	3.38(0.63)	3.41(0.62)	3.40(0.6)	3.33(0.67)	3.31(0.72)
Health literacy (n [%])	3.72(0.66)	3.59(0.66)	3.49(0.68)	3.43(0.78)	3.57(0.73)	3.56(0.7)	3.45(0.71)	3.45(0.81)
VL (mean, [SD])								
Functional VL	2.67 (0.71)	2.61(0.74)	2.57(0.74)	2.66(0.83)	2.62 (0.77)	2.78(0.64)	2.67(0.6)	2.53(0.62)
Interactive/critical VL	3.02(0.63)	2.82(0.61)	2.62(0.56)	2.66(0.63)	2.69 (0.62)	2.77(0.65)	2.67(0.59)	2.53(0.62)

VL, vaccine literacy.

SD, standard deviation; VL, vaccine literacy.

not getting vaccinated for both the pregnant women and the mothers of young children was being “worried about adverse reactions.” A larger proportion of the mothers of young children indicated being “worried about adverse reactions,” “I do not think it is very effective in preventing infection and aggravation,” and “I do not trust the components of vaccines” compared to the pregnant women. On the other hand, more pregnant women listed being “concerned about the potential effects on my fetus” and “concerned about the potential effects on lactation” as reasons why they were hesitant to get vaccinated.

Among the pregnant women, the strongest difference between groups by interactive/critical VL skill level was observed for the responses “I am worried about adverse reactions,” “I am worried about its effect on the fetus,” and “I am worried about its effect on breastfeeding,” with a higher proportion of women with lower VL interactive/critical skills selecting these reasons. Among the mothers of young children, the strongest difference between groups by functional VL skill level was observed for the responses “the vaccine is not effective in the prevention of infection and aggravation” and “I can’t trust the ingredients of the vaccine,” with a higher proportion of women with lower functional VL skills selecting these reasons.

The sources the pregnant women and mothers of young children used to collect reliable information on COVID-19 and the COVID-19 vaccine are shown in Table 5 by VL level. Compared with women with low interactive/critical VL skills, those with higher skills tended to rely more on medical doctors, experts, and official government and academic websites. A higher proportion of the pregnant women listed medical doctors as their primary source of information compared with the mothers of young children. For both the pregnant women and mothers of young children, the proportion who answered that they were not using any of the listed information resources was highest among the low interactive/critical VL skills group.

8. Discussion

In our population-based, internet-based questionnaire survey, the proportion of respondents who were COVID-19 vaccine-hesitant, which we defined as those unwilling to take the vaccine or who had adopted a “wait and see” approach, was 51.1 % and 31.9 % among pregnant women and mothers of young children in Japan, respectively. We found that lower VL was correlated with vaccine hesitancy in the context of the COVID-19 pandemic. Interestingly, functional and interactive/critical VL skills had different impacts on vaccine acceptance. Interactive/critical skills were strongly related with vaccine acceptance among pregnant women, while functional skills showed more influence for the mothers of

young children. To our knowledge, this is the first study to investigate vaccine hesitancy and VL among pregnant women and mothers of young children and the associated influencing factors. Our findings can help inform effective interventions to improve vaccine acceptance rates among pregnant women and mothers of young children.

Pregnant women demonstrate relatively high vaccine hesitancy compared to the general population [13,25]. Based on a survey of women in 16 countries, 48 % of pregnant women, compared with 27 % of non-pregnant women, were reluctant to get the COVID-19 vaccine [25]. In one Japanese survey, 28 % of women in their 20 s were unsure about their intention to be vaccinated as of September 2020 [30]; however, no previous study has investigated pregnant women’s vaccination intention in Japan. Our study revealed that nearly half of the pregnant women surveyed were COVID-19 vaccine hesitant, suggesting that the rate in Japan is close to those in other countries [31].

The risk factors for vaccine hesitancy among pregnant women and mothers of young children identified in our study included lower education levels, not being in full-time employment, lower income, lower health literacy, and fewer infection prevention practices. These factors are comparable to those that have been reported in previous research [31]. Previous research has shown that explicit communication about the safety of COVID-19 vaccines, trust in public health agencies, compliance with mask guidelines, higher education levels, and socioeconomic status are the factors most strongly associated with COVID-19 vaccine acceptance during pregnancy [31]. Increased age, underlying health conditions, and the trimester of pregnancy, which are known to increase the risk of COVID-19 complications in pregnancy, did not show any association with vaccine hesitancy in our previous study[9].

We found that vaccine hesitancy was correlated with the VL levels of pregnant women and mothers of young children. The VL questionnaire used assessed both the functional and interactive/critical skill components of VL, unlike some previous research that has focused only on functional VL skills [17]. Vaccine literacy, especially interactive/critical skills, is receiving more attention in the context of the COVID-19 pandemic. Using both subscales led us to understand not only participants’ knowledge but also their attitudes toward the information they receive and their decision-making.

VL levels likely vary among different populations. The mean VL scores in our study were lower than those found in the Italian population [22] but similar to those identified in the Croatian adult population [23]. The Japanese population has been reported to have lower health literacy than Western countries [32], which may have contributed to this difference. However, as this is the first study measuring COVID-19 VL in the Japanese population, and since our study targeted the specific populations of pregnant

Table 3
Multivariate Poisson regression, difference-in-difference analysis of the risk ratio of COVID-19 vaccine hesitancy and VL among pregnant women and mothers of young children.

	Pregnant women			Mothers of young children		
	Risk Ratio	95 % CI	p-value	Risk Ratio	95 % CI	p-value
Functional VL level						
High	Ref	–	–	ref	–	–
Medium	0.78	0.58–1.06	0.108	0.97	0.83–1.13	0.677
Low	0.81	0.60–1.09	0.181	1.37	1.18–1.60	<0.001
Interactive/critical VL level						
High	Ref	–	–	ref	–	–
Medium	1.60	1.19–2.17	0.002	0.92	0.79–1.08	0.296
Low	1.69	1.23–2.31	<0.001	1.28	1.10–1.49	0.002

Risk of vaccine hesitancy among pregnant women compared to mothers of young children adjusted for Functional VL score: OR 2.53(95 %CI 2.08, 3.09).
Risk of vaccine hesitancy among pregnant women compared to mothers of young children adjusted for Interactive VL score: OR 1.63(95 %CI 1.31, 2.02).
CI = confidence interval; VL, vaccine literacy.

Table 4
Reasons for vaccine hesitancy by functional VL skill level and interactive/critical VL skill level.

	Pregnant women								Mothers of young children							
	Functional VL level				Interactive/critical VL level				Functional VL level				Interactive/critical VL level			
	Low (n = 493) n (%)	Medium (n = 503) n (%)	High (n = 643) n (%)	p- value	Low (n = 473) n (%)	Medium (n = 585) n (%)	High (n = 581) n (%)	p- value	Low (n = 1636) n (%)	Medium (n = 1833) n (%)	High (n = 2219) n (%)	p- value	Low (n = 1946) n (%)	Medium (n = 1869) n (%)	High (n = 1873) n (%)	p- value
I am worried about adverse reactions.	234 (47.5)	200(39.8)	264 (41.1)	0.029	243 (51.4)	252(43.1)	203 (34.9)	<0.001	570 (34.8)	500 (27.3)	575 (25.9)	<0.001	668(34.3)	477(25.5)	500(26.7)	<0.001
I am concerned about the potential effects on my fetus.	242 (49.1)	202(40.2)	265 (41.2)	0.007	241(51)	265(45.3)	203 (34.9)	<0.001	385(23.5)	329(18)	378(17)	<0.001	-	-	-	-
I am concerned about the potential effects on lactation.	198 (40.2)	153(30.4)	220 (34.2)	0.005	194(41)	216(36.9)	161 (27.7)	<0.001	231(14.1)	170(9.3)	197(8.9)	<0.001	418(21.5)	333(17.8)	341(18.2)	0.007
I do not think it is very effective in preventing infection.	82(16.6)	38(7.6)	90(14)	<0.001	66(14)	67(11.5)	77(13.3)	0.445	138(8.4)	88(4.8)	100(4.5)	<0.001	227(11.6)	158(8.5)	213(11.4)	0.002
I do not think it is very effective in preventing aggravation.	46(9.3)	22(4.4)	58(9)	0.004	39(8.3)	38(6.5)	49(8.4)	0.4	422(25.8)	331(18.1)	356(16)	<0.001	131(6.7)	76(4.1)	119(6.4)	0.001
I do not trust the components of vaccines.	156 (31.6)	126(25.1)	172 (26.8)	0.053	149 (31.5)	159(27.2)	146 (25.1)	0.067	45(2.8)	34(1.8)	44(2)	0.147	440(22.6)	326(17.4)	343(18.3)	<0.001
I do not think I will get infected.	11(2.2)	9(1.8)	17(2.6)	0.626	14(3)	7(1.2)	16(2.7)	0.096	80(4.9)	81(4.4)	79(3.6)	0.112	49(2.5)	28(1.5)	46(2.5)	0.054
I believe I have a low risk of getting seriously ill.	20(4.1)	17(3.4)	27(4.2)	0.76	29 (6.1)	16 (2.7)	19 (3.3)	0.011	570(34.8)	500(27.3)	575(25.9)	<0.001	88(4.5)	66(3.5)	86(4.6)	0.195

VL, vaccine literacy.

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Table 5
Sources pregnant women and mothers of young children use to collect reliable information on COVID-19 and the COVID-19 vaccination by VL level.

	Pregnant women								Mothers of young children							
	Functional VL level				Interactive/critical VL level				Functional VL level				Interactive/critical VL level			
	Low (n = 493) n (%)	Medium (n = 503) n (%)	High (n = 643) n (%)	p- value	Low (n = 473) n (%)	Medium (n = 585) n (%)	High (n = 581) n (%)	p- value	Low (n = 1636) n (%)	Medium (n = 1833) n (%)	High (n = 2219) n (%)	p- value	Low (n = 1946) n (%)	Medium (n = 1869) n (%)	High (n = 1873) n (%)	p- value
Family, friends, colleagues	418 (84.8)	406 (80.7)	481(74.8)	<0.001	353 (74.6)	500(85.5)	452(77.8)	<0.001	1337 (81.7)	1499(81.8)	1703(76.8)	<0.001	1489 (76.5)	1576(84.3)	1474 (78.7)	<0.001
Doctors	140 (28.4)	161 (32)	212 (33)	0.237	269 (56.9)	438(74.9)	419(72.1)	<0.001	779 (47.6)	891 (51.4)	1126(50.7)	0.135	1122 (57.7)	1130(55.2)	1105 (53.8)	<0.001
Experts	280 (56.8)	326(64.8)	341(53)	<0.001	203 (42.9)	276(64.3)	368(63.3)	<0.001	895 (54.7)	1059(57.8)	1098(49.5)	<0.001	867(44.6)	1119(59.9)	1066 (56.9)	<0.001
Official websites (Government, academic)	210 (42.6)	271(53.9)	301(46.8)	0.001	153 (32.4)	312(53.3)	317(54.6)	0.001	706(43.2)	913(50)	954(43)	<0.001	630(32.4)	995(53.2)	948(50.6)	<0.001
Social media	174 (35.3)	177(35.2)	178(27.7)	0.006	126 (26.6)	207(35.4)	196(33.7)	0.007	641(39.2)	671(36.6)	698(31.5)	<0.001	587(30.2)	702(37.6)	721(38.5)	<0.001
Newspapers, books, magazines	92(18.7)	88(17.5)	103(16.0)	0.499	69(14.6)	117(20)	97(16.7)	0.062	268(16.4)	322(17.6)	368(16.6)	0.594	269(13.7)	331(17.7)	360(19.2)	<0.001
TV, radio	388 (68.6)	379(75.4)	435(67.7)	0.011	314 (66.4)	441(75.4)	397(68.3)	0.003	1176 (71.9)	1423(77.6)	1569(70.7)	<0.001	1408 (72.4)	1446(77.4)	1314 (70.2)	<0.001
Internet news	280 (56.8)	331(65.8)	351(54.6)	<0.001	261 (55.2)	374(63.9)	327(56.3)	0.005	1008 (61.6)	1185(64.7)	1277(57.6)	<0.001	1148(59)	1232(65.9)	1090 (58.2)	<0.001
Celebrity	79(16.0)	70(13.9)	69(10.7)	0.030	44(9.3)	101(17.3)	73(12.6)	0.001	267(16.3)	247(13.5)	11.5(11.5)	<0.001	227(11.7)	297(15.9)	245(13.1)	0.001
Did not use any of the above	13(2.6)	11(2.2)	32(5.0)	0.019	26(5.5)	5(0.9)	25(4.3)	<0.001	66(4.0)	45(2.5)	119(5.4)	<0.001	107(5.5)	39(2.1)	84(4.5)	<0.001

women and women with young children, direct comparisons between countries should be conducted cautiously. It is a distinctive feature of our study that different categories of VL were found to be associated with COVID-19 vaccine hesitancy among mothers of young children and pregnant women, with interactive/critical VL skills having a more significant impact on pregnant women, and functional VL skills more significantly affecting mothers of young children. Tailored interventions that consider these different effects should be developed to improve vaccine acceptance rates in different populations.

The reasons that individuals are vaccine hesitant differ by person and population, and those given by pregnant women are reported to differ from the general population [13,33]. One main concern of pregnant women is vaccine safety [13,33]. In our study, vaccine-hesitant pregnant women were mainly worried about the vaccine's safety for fetuses and breastfed babies. Mothers of young children were also hesitant due to a general lack of trust in vaccines. In addition, our results suggest these different reasons for vaccine hesitancy may result in different types of VL skills that influence vaccine acceptance. Functional VL skills, which allow individuals to correctly understand vaccines, is required to build trust in vaccination. On the other hand, interactive/critical VL skills, that is, skills to communicate and critically analyze information, are required to differentiate facts from false information and may be more important for relieving concerns about the possible long-term adverse effects of vaccines on children.

Our results suggest that promoting vaccine literacy, as well as communications tailored according to VL level, could help reduce vaccine hesitancy [34]. Conveying vaccine information in an easily understandable manner is helpful for those with lower functional VL skills, whereas checking the credibility of sources and discussing information with others is effective in increasing interactive/critical VL skills [35]. One reason that we only observed functional VL skills to be correlated with vaccine hesitancy among mothers of young children and not among pregnant women may be that pregnant women have easy access to consultations with doctors and to updated vaccine information during regular antenatal checkups. Thus, pregnant women would be more likely to obtain relevant information regardless of their functional VL levels. To address information deficiencies among mothers of young children, the provision of such information to child-rearing women through well-child visits may also prove to be an effective intervention for women with low functional VL skills. On the other hand, we found that women with high interactive/critical VL skills more frequently obtained reliable information from authorized resources, such as medical doctors and official government and academic websites. Increasing the opportunities for women to communicate their concerns and helping them critically analyze their sources of information may lead to enhancing interactive/crucial VL skills and lowering vaccine hesitancy.

The strength of this study is that it included a large population-based survey during the COVID-19 pandemic among pregnant women and mothers of young children. This study also investigated two VL components, using a questionnaire that has been previously used in multiple countries [22,23]. Furthermore, this study is the first to provide findings concerning the relationship between vaccine hesitancy and detailed VL components. However, our study is not without limitations. First, the data were collected through an internet survey, meaning selection biases were possibly present. However, when comparing the average income of households with children in our study with 2018 national survey data, it can be seen that data in relation to socioeconomic characteristics such as income and education level in our study were consistent with 2018 national survey data [36]. Second, the concept of VL is relatively new; thus, there may have been unknown confounders. Finally, our findings could differ from what would be found in

today's context since vaccination rates were lower in Japan (50 %) at the time of the survey than currently (78 % as of December 2021). Nevertheless, the vaccination and information about its safety had already become widely available during the study period, and vaccination had already been recommended for pregnant women in Japan.

To our knowledge, this is the first study to investigate vaccine hesitancy and VL among pregnant women and mothers of young children. A key finding was that interactive/critical VL skills could have a greater impact on pregnant women, while functional VL skills could have a greater impact on mothers of young children. Our results confirm that promoting VL can enhance COVID-19 vaccine acceptance. When considering effective ways to deliver information on vaccines, it is important to tailor this information to the target population's VL skill level.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Bioethics Review Committee of Osaka International Cancer Institute, Japan (no. 20,084 on June 19, 2020; no. 20084-6 at Dec 14, 2021).

Informed Consent Statement: Informed consent was obtained electronically, and all participants were informed of their right to withdraw from the study at any time.

Data Availability Statement: The data that support the findings of this study are available upon reasonable request. However, restrictions apply to the availability of this data because data associated with personal identification cannot be shared. If any person wishes to verify our data, they are most welcome to contact the corresponding author.

CRediT authorship contribution statement

Yoko Takahashi: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Kazue Ishitsuka:** Methodology, Formal analysis, Writing – review & editing. **Makiko Sampei:** Resources. **Sumiyo Okawa:** Resources, Data curation, Writing – review & editing. **Yoshihiko Hosokawa:** Resources. **Akira Ishiguro:** Writing – review & editing. **Takahiro Tabuchi:** Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Naho Morisaki:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

Data availability

The authors do not have permission to share data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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