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Attitudes toward future child-rearing among male and female adults without children in different prefectures at 11 years after the Fukushima Daiichi Nuclear Power Plant accident

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Abstract – This study aimed to determine whether confidence in future childbearing and child-rearing in relation to radiation exposure differs among people without children in Fukushima Prefecture, its neighboring prefectures (Tochigi, Ibaraki, and Miyagi), and other prefectures, and among men and women at 11 years after the nuclear accident. In February 2022, a cross-sectional online survey was conducted using an Internet research company. A total of 985 people were surveyed: 240 from Fukushima, 305 from neighboring prefectures, and 440 from other prefectures. The proportion of women who were confident about future childbearing was low and the confidence was associated with radiation-related risk perceptions in both Fukushima and neighboring prefectures. The results suggest that the more people want to have children in the future, the more likely they will be able to discuss radiation, and the less likely they will be able to believe that radiation has a low impact on their partners. Therefore, it is necessary to create an environment where people can openly discuss radiation, and to examine factors that affect confidence in future childbearing and child-rearing by gender and prefecture.

Keywords: Fukushima Daiichi Power Plant / radiation effects / childbearing intentions / epidemiology

1 Background

The experience of radiation exposure associated with the Fukushima Daiichi Nuclear Power Plant accident following the Great East Japan Earthquake of March 11, 2011, has had a significant impact on the mental health of many people (Ishii *et al.*, 2022; Ito *et al.*, 2018a, 2018b; Suzuki *et al.*, 2015). Although this radiation exposure has been reported to have had little impact on physical health (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2015), 38.3%–42.6% of mothers who experienced radiation exposure during pregnancy and childbirth in Fukushima Prefecture in 2011–2012 reported still feeling concerned about prejudice at 8–9 years after the accident, in 2019–2020 (Ito *et al.*, 2018a; Radiation Medical Science Center for the Fukushima Health Management Survey, 2022). In 2018, 7 years after the accident, 27.5% of female university students who experienced radiation exposure in Fukushima Prefecture

were still unsure about having a baby in the future, and 40.0%–45.0% of these students thought that radiation exposure was likely to cause health effects (Ito *et al.*, 2023).

After the accident, the physical and mental health of all pregnant women in Fukushima Prefecture was assessed (Ishii *et al.*, 2022; Ito *et al.*, 2018a). In addition, a previous study (Ito *et al.*, 2023) conducted to assess confidence in future childbearing and perceived risk of radiation exposure affecting the physical health of female students in Fukushima Prefecture who had experienced radiation exposure. However, in prefectures close to Fukushima, such as Tochigi, Ibaraki, and Miyagi, no surveys on childbirth/child-rearing anxiety associated with radiation exposure have been conducted, despite the proximity of these prefectures to the site of the nuclear accident. Most surveys on childbirth and child-rearing concerns have focused on expectant and nursing mothers and women, and the actual situation for men has not been clarified. According to a web-based survey conducted by the Ministry of the Environment from FY2021 to FY2023, the level of awareness of health risks associated with radiation exposure differs among Fukushima Prefecture, the Tohoku region

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(Aomori, Akita, Iwate, Miyagi, and Yamagata) excluding Fukushima Prefecture, and Tokyo, with the proportion of those who believe that there are health risks associated with radiation exposure reported to be higher among residents of other prefectures than among residents of Fukushima Prefecture (Ministry of the Environment, 2023). In addition, a higher percentage of women than men has been shown to have a higher perception of health risks (Ministry of the Environment, 2023). In Fukushima Prefecture, it is widely believed that discussing the disaster and issues related to radiation exposure with acquaintances and friends has become more difficult because over 10 years have passed since the accident. Among the 32,699 residents of the affected areas in Fukushima Prefecture, those who have no one to talk to or ask for help are reported to have higher levels of psychological stress (Horikoshi *et al.*, 2021). However, the level of anxiety regarding future childbirth and childcare among men in Fukushima Prefecture and people in neighboring prefectures remains unclear.

Given this background, the present study aimed to determine the actual level of confidence in future childbearing and child-rearing at 11 years after the nuclear accident and to determine whether radiation-related factors affect future childbearing expectations. We also investigated whether radiation-related factors affect confidence in future childbearing and child-rearing among those who hope to have children in the future through a comparison of Fukushima Prefecture, its neighboring prefectures (Tochigi, Ibaraki, and Miyagi), and other prefectures, as well as by gender. The findings may reveal whether support is needed for men and women in prefectures neighboring the affected prefectures.

2 Methods

2.1 Study design and participants

A cross-sectional study was conducted in February 2022 using a questionnaire survey via an Internet research company. The inclusion criteria were between 18 and 40 years of age, male or female gender, and having no children. The survey and analysis were conducted by dividing the respondents into three groups according to the prefecture in which they resided on March 11, 2011, the date of the Great East Japan Earthquake: Fukushima Prefecture, prefectures neighboring Fukushima (Tochigi, Ibaraki, and Miyagi), and other prefectures. A total of 985 people participated in the survey: 240 residents of Fukushima Prefecture (67 males and 173 females), 305 residents of prefectures neighboring Fukushima (143 males and 162 females), and 440 residents of other prefectures (212 males and 228 females).

2.2 Questionnaire

2.2.1 Personal characteristics

Regarding the questionnaire items, data on the respondents' personal characteristics were obtained from their responses to single-item questions on age, gender, marital status, family structure, hopes for future children, knowledge

about radiation, radiation advisors, stress in daily life, and concerns about radiation effects on a future partner. The scales used were the Fukushima Future Parents Attitude Measure (FPAM) (Ito *et al.*, 2018a), the Rosenberg Self-Esteem Scale (RSES) (Rosenberg, 1965), and the World Health Organization-Five Well-Being Index (WHO-5) (Awata *et al.*, 2007), Communicative and Critical Health Literacy (Ishikawa *et al.*, 2008), the Attitudes Towards Seeking Professional Psychological Help Scale-Short Form (ATSPPH-SF) (Elhai *et al.*, 2008), the 2-item Depression Rating Scale (Mishina *et al.*, 2009), and the Perception of Radiation Health Effects Risk survey (Yabe *et al.*, 2014).

2.2.2 Fukushima Future Parents Attitude Measure (FPAM)

The FPAM measures attitudes toward childbirth and infant care after radiation exposure (Ito *et al.*, 2018a). Respondents are instructed to answer questions on the assumption that they will be living and raising a family in Fukushima Prefecture. The FPAM consists of two factors: three items measuring "Caring for a baby" and three items measuring "Giving birth to a baby." The responses are rated on a 4-point Likert scale, from 1 = strongly agree to 4 = strongly disagree. The score for each item ranges from 3 to 12, with lower scores indicating more confidence in the future delivery and care of an infant.

2.2.3 Rosenberg Self-Esteem Scale (RSES)

The RSES is a widely used measure for assessing self-esteem (Rosenberg, 1965). It is composed of 10 items rated on a four-point Likert-type scale, from 10 = strongly disagree to 40 = strongly agree, with higher scores indicating higher self-esteem.

2.2.4 World Health Organization-Five Well-Being Index (WHO-5)

The WHO-5 is a self-administered five-item scale used to measure quality of life (Awata *et al.*, 2007). Each item measures the respondents' sense of positive well-being during the previous 2 weeks, with responses rated on a six-point ranking scale ranging from zero to five, with higher scores indicating greater well-being.

2.2.5 Communicative and critical health literacy

The Health Literacy Scale is composed of three items on communicative health literacy and two items on critical health literacy (Ishikawa *et al.*, 2008). Communicative health literacy, as defined by Nutbeam *et al.* (1998), is the skill to participate actively in daily activities, to draw information from various forms of communication, and to apply new information to changing situations. Critical health literacy also involves the skill to analyze information critically and use that information to control life events and situations more effectively (Nutbeam, 1998). Response options are rated on a five-point Likert-type scale, ranging from 1 = strongly disagree to 5 = strongly agree, with higher scores indicating better health literacy.

2.2.6 Attitudes towards seeking professional psychological help scale-short form (ATSPPH-SF)

The self-administered 10-item ATSPPH-SF assesses attitudes toward mental health treatment (Elhai *et al.*, 2008). Response options are rated on a four-point Likert-type scale, from 0 = disagree to 3 = agree. Total scores range from 0 to 30, with higher scores indicating a more positive attitude.

2.2.7 Depressive symptoms

The following two items were used to screen for depressive symptoms: “During the past month, have you often felt down, depressed, or hopeless?” and “During the past month, have you often found little interest or pleasure in doing things?” (Mishina *et al.*, 2009). Participants who answered yes to at least one of these questions were classified as displaying depressive symptoms.

2.2.8 Perceptions of the risk of radiation effects on health

A screening tool composed of two items related to delayed health effects and genetic effects associated with radiation exposure was adapted from the Fukushima Health Management Survey (Fukushima Prefecture & Fukushima Medical University, 2011; Yabe *et al.*, 2014). The response options were rated on a four-point Likert-type scale, from 1 = very unlikely to 4 = very likely. Total scores ranged from 1 to 4, with higher scores indicating perceptions of more adverse health effects.

2.3 Statistical analysis

The following five types of statistical analyses were performed in the present study. First, a chi-square test (residual analysis) and one-factor analysis of variance (Tukey’s method) were conducted to examine factors affecting childbearing and child-rearing anxiety related to radiation exposure by gender and place of residence at the time of the Great East Japan Earthquake (Fukushima Prefecture, neighboring prefectures, and other prefectures). Second, Pearson’s product-rate correlation coefficients were obtained to examine the strength of the relationship between the presence or absence of hope for future children and radiation-related factors. Third, to examine the strength of the relationship between hope for future children and radiation-related factors, we used hope for future children as the dependent variable, radiation-related factors as the independent variable, and other factors as adjustment variables in the logistic regression analysis. Fourth, Pearson’s correlation coefficients were calculated to examine factors associated with childbearing and parenting anxiety related to radiation exposure and health risk perception related to radiation exposure among those who wanted to have children in the future. Finally, to examine the factors affecting childbearing and child-rearing anxiety related to radiation exposure among those who wanted to have children in the future, multiple regression analysis was conducted using the forced entry method with the FPAM scale as the dependent variable, radiation-related factors as the independent variable, and demographic items as adjustment variables. All analyses

were conducted using IBM SPSS ver. 25.0 for Windows (IBM SPSS Japan, Tokyo, Japan).

2.4 Research ethics

This study was approved by the Kitasato University School of Nursing Ethics Committee (No. 2021-9-2). The purpose of the study was fully explained to respondents in a cover letter to the questionnaire. All respondents were informed that they would not be disadvantaged by responding or refusing to participate. All respondents were also asked to confirm their consent to participate in the study.

3 Results

A total of 985 individuals responded to the questionnaire: 240 (67 males and 173 females) from Fukushima Prefecture, 305 (143 males and 162 females) from prefectures neighboring Fukushima Prefecture, and 440 (212 males and 228 females) from other prefectures.

The percentages of the results of each scale score by gender and by place of residence at the time of the Great East Japan Earthquake are shown in Table 1, and the mean values are shown in Table 2. Basic attributes of respondents that could not be fully described in Tables 1 and 2 were added in Supplement 1. A significantly higher proportion of women answered in neighboring prefectures “Likely” for “Perception of radiation risk: Genetic effects” compared with the other groups ($n=63$ [38.9%]; adjusted residuals = 2.4). Regarding “Giving birth to a baby,” women in Fukushima Prefecture (mean [M] = 8.0, standard deviation [SD] = 2.0) had significantly higher scores than did men in all three groups: Fukushima (M = 7.2, SD = 1.7), neighboring prefectures (M = 7.3, SD = 1.8), and other prefectures (M = 7.2, SD = 1.8). Moreover, women in other prefectures (M = 7.8, SD = 2.1) had significantly higher scores than did men in other prefectures (M = 7.2, SD = 1.8; $p < 0.001$). Regarding the FPAM item “Caring for a baby,” men in other prefectures (M = 7.4, SD = 2.3) had significantly higher scores than did women in neighboring prefectures (M = 6.9, SD = 2.6; $p = 0.036$).

The distribution of the main independent and dependent variables is also shown in Table 1 and 2. The variable with a significant difference in distribution across four groups was the numbers of those who answered that they were not confident in giving birth. The proportions were 17 (25.4%) men and 74 (42.8%) women in Fukushima Prefecture, 38 (26.6%) men and 57 (35.2%) women in neighboring prefectures, and 52 (24.5%) men and 84 (36.8%) women in other prefectures ($p < 0.001$).

To examine radiation-related factors affecting desired future offspring, Pearson’s product-rate correlation coefficients were calculated (Supplement 2), and logistic regression analysis using the forced entry method was conducted with desired future offspring as the dependent variable, radiation-related factors as the independent variable, and other factors as adjustment variables. The items for which significant differences were found are shown in Table 3, and the results for all items that were entered are shown in Supplement 3. The factors associated with the desire to have children in the future were “Presence of a person to give advice about radiation (odds ratio

Table 1. Comparison of proportion of survey item scores by sex and prefecture (Fukushima, neighboring prefectures, and other prefectures).

	Fukushima Prefecture						Neighboring Prefectures						Other Prefectures						P-value
	Male (n = 67) ¹			Female (n = 173) ²			Male (n = 143) ³			Female (n = 162) ⁴			Male (n = 212) ⁵			Female (n = 228) ⁶			
	n	%	AR ^a	n	%	AR ^a	n	%	AR ^a	n	%	AR ^a	n	%	AR ^a	n	%	AR ^a	
Future child desires																			
Desired	39	58.2	-0.3	106	61.3	0.3	77	53.8	-1.7	110	67.9	2.2	114	53.8	-2.2	147	64.5	1.5	0.035
Not desired	28	41.8	0.3	67	38.7	-0.3	66	46.2	1.7	52	32.1	-2.2	98	46.2	2.2	81	35.5	-1.5	
Depressive symptoms																			
Yes	20	29.9	-1.8	56	32.4	-2.3	78	54.5	3.8	58	35.8	-1.2	85	40.1	0.0	98	43.0	1.0	0.001
No	47	70.1	1.8	117	67.6	2.3	65	45.5	-3.8	104	64.2	1.2	127	59.9	0.0	130	57.0	-1.0	
Availability of radiation consultant																			
Presence	33	49.3	-1.7	128	74.0	4.4	65	45.5	-3.6	108	66.7	2.1	100	47.2	-4.0	148	64.9	2.0	0.000
Absence	34	50.7	1.7	45	26.0	-4.4	78	54.5	3.6	54	33.3	-2.1	112	52.8	4.0	80	35.1	-2.0	
Knowledge of nuclear power and radiation																			
With knowledge	4	6.0	2.3	2	1.2	-1.0	3	2.1	0.0	2	1.2	-0.9	6	2.8	0.8	4	1.8	-0.5	0.000
Somewhat knowledgeable	17	25.4	2.7	33	19.1	2.1	27	18.9	1.8	13	8.0	-2.4	35	16.5	1.1	14	6.1	-3.9	
Not very knowledgeable	29	43.3	-0.3	91	52.6	2.3	58	40.6	-1.1	83	51.2	1.8	93	43.9	-0.3	88	38.6	-2.2	
Without knowledge	17	25.4	-2.3	47	27.2	-3.5	55	38.5	-0.1	64	39.5	0.2	78	36.8	-0.7	122	53.5	5.2	
Radiation effects on partners																			
Concerned	4	6.0	-0.6	16	9.2	0.7	9	6.3	-0.8	17	10.5	1.3	16	7.5	-0.3	17	7.5	-0.4	0.882
Slightly concerned	26	38.8	1.4	47	27.2	-1.3	53	37.1	1.6	47	29.0	-0.7	65	30.7	-0.3	71	31.1	-0.1	
Do not care too much	20	29.9	-1.1	62	35.8	0.0	48	33.6	-0.6	61	37.7	0.5	80	37.7	0.7	82	36.0	0.0	
Do not care	17	25.4	0.1	48	27.7	1.0	33	23.1	-0.5	37	22.8	-0.6	51	24.1	-0.3	58	25.4	0.3	
FPAM: Giving birth to a baby^b																			
Confident	50	74.6	1.3	99	57.2	-3.1	105	73.4	1.7	105	64.8	-0.7	160	75.5	2.9	144	63.2	-1.5	0.001
Not confident	17	25.4	-1.3	74	42.8	3.1	38	26.6	-1.7	57	35.2	0.7	52	24.5	-2.9	84	36.8	1.5	
FPAM: Caring for a baby^b																			
Confident	50	74.6	0.3	122	70.5	-0.8	103	72.0	-0.3	129	79.6	2.1	148	69.8	-1.2	167	73.2	0.1	0.368
Not confident	17	25.4	-0.3	51	29.5	0.8	40	28.0	0.3	33	20.4	-2.1	64	30.2	1.2	61	26.8	-0.1	
Perception of radiation risk: Delayed effects																			
Unlikely ^c	48	71.6	1.2	124	71.7	2.1	93	65.0	0.0	95	58.6	-1.8	141	66.5	0.6	138	60.5	-1.6	0.082
Likely ^c	19	28.4	-1.2	49	28.3	-2.1	50	35.0	0.0	67	41.4	1.8	71	33.5	-0.6	90	39.5	1.6	
Perception of radiation risk: Genetic effects																			
Unlikely ^c	50	74.6	1.0	126	72.8	1.2	103	72.0	0.8	99	61.1	-2.4	151	71.2	0.8	151	66.2	-1.0	0.116
Likely ^c	17	25.4	-1.0	47	27.2	-1.2	40	28.0	-0.8	63	38.9	2.4	61	28.8	-0.8	77	33.8	1.0	

^aAR = adjusted residuals (considered significantly different if greater than 1.96), ^b the respondents who answered "not very confident" or "not confident" on all items of the FPAM subscale were defined as "not confident"; ^c the "Very unlikely" and "Unlikely" were defined as Unlikely, and the "Very likely" and "Likely" were defined as Likely.

Table 2. Comparison of mean of survey item scores by sex and prefecture (Fukushima, neighboring prefectures, and other prefectures).

	Fukushima Prefecture			Neighboring Prefectures			Other Prefectures			P-value			
	Male (n = 67) ¹		SD	Male (n = 143) ³		SD	Male (n = 212) ⁵		SD				
	M	SD		M	SD		M	SD					
Age	31.0	6.4 ^{4,6}	29.9	6.2 ⁴	29.2	4.5	27.9	4.7 ^{1,2,5}	29.7	4.6 ⁴	28.5	4.4 ¹	0.000
FPAM: Giving birth to a baby	7.2	1.7 ²	8.0	2.0 ^{1,3,5}	7.3	1.8 ²	7.8	1.8	7.2	1.8 ^{2,6}	7.8	2.1 ⁵	0.000
FPAM: Caring for a baby	7.1	2.4	6.9	2.8	7.3	2.3	6.6	2.3 ⁵	7.4	2.3 ⁴	6.9	2.6	0.036
WHO-5	18.2	6.6	17.5	5.6	16.6	6.0	17.2	6.3	16.8	6.2	16.5	6.4	0.274
HL: Communicative	10.4	2.7	10.2	2.4	10.1	2.6	10.3	2.4	10.3	2.6	10.5	2.4	0.820
HL: Critical	6.5	1.7	6.5	1.6	6.5	1.7	6.3	1.7	6.6	1.8	6.6	1.8	0.813
Self-esteem	22.7	6.4	22.3	4.6	22.8	5.5	22.5	5.6	23.4	5.7	22.4	5.8	0.380
ATSPPH-SF	24.5	4.0	24.7	4.2	23.7	4.0	24.9	3.8	24.6	4.0	24.6	4.4	0.244

The columns with M and SD were calculated using one-way analysis of variance and Tukey’s method. Superscript numbers indicate areas of significant difference at the 5% level of significance using the Tukey method. For example, “4,6” for the age of males in Fukushima Prefecture indicates that there was a significant difference between females in the neighboring prefectures and those in other prefectures.

[OR]=4.1, 95% confidence interval [CI]=1.0–16.3)” and “Concerns about radiation effects on a future partner” (OR=2.0, 95% CI=1.2–3.4) for men and women in Fukushima Prefecture, respectively, and both “Presence of a person to give advice about radiation” (OR=4.4, 95% CI=1.9–10.3) and “Concerns about radiation effects on a future partner” (OR=2.4, 95% CI=1.5–4.1) for women in neighboring prefectures, and both “Presence of a person to give advice about radiation” (OR=2.4, 95% CI=1.3–4.7) and “Presence of a person to give advice about radiation” (OR=2.2, 95% CI=1.1–4.2), respectively, for men and women in other prefectures.

To examine the factors associated with the FPAM scale among those who wanted to have children in the future, Pearson’s correlation coefficients between items were calculated (Supplement 4), and then multiple regression analysis using the forced entry method was performed. The items with significant differences are shown in Tables 4 and 5, and the results for all input items are shown in Supplements 5 and 6. Focusing on the dependent variable related to radiation, the factors related to “Giving birth to a baby” were “Risk perception of radiation health effects: genetic effects” (standardized $\beta=0.3$) among women in Fukushima Prefecture, “Concerns about radiation effects on a future partner” (standardized $\beta=-0.3$) and “Risk perception of radiation health effects: delayed effects” (standardized $\beta=0.3$) among men from other prefectures. Of note, among the covariates, the direction of association with ATSPPH-SF was opposite between women in Fukushima and neighboring prefectures.

Factors related to “Caring for a child” were “Presence of a person to give advice about radiation” (standardized $\beta=0.2$) and “Knowledge of radiation” (standardized $\beta=0.3$) among men in neighboring prefectures, and “Presence of a person to give advice about radiation” (standardized $\beta=0.2$) and “Risk perception of radiation health effects: genetic effects” (standardized $\beta=-0.4$) among women in other prefectures.

4 Discussion

The results of this survey suggest that, at 11 years after the Fukushima Daiichi Nuclear Power Plant accident, confidence in future childbearing and child-rearing among people without children differs by prefecture (Fukushima, neighboring prefectures, and other prefectures) and gender. Women in Fukushima Prefecture had the lowest confidence in future childbearing (57.2% vs. 63.2%–75.5%). In a survey of female university students in Fukushima Prefecture, 83.2% and 80.6% were confident in their future childbearing in 2015 and 2018, respectively, and 86.4% and 90.7% in their future child-rearing (Ito *et al.*, 2023), a higher percentage of those confident than the Fukushima Prefecture women in this survey. The respondents in the present study had a mean age of 29.9 years and did not currently have children. Therefore, it is possible that those who are confident about future childbearing and child-rearing were excluded because they already had children. These results suggest that support to increase confidence in future childbearing is needed for women in Fukushima Prefecture who do not have children.

The results of this survey also suggest that factors such as radiation-related support associated with the place of residence

Table 3. Multiple regression analysis of Factors associated with "desired future children" by sex and prefectures.

Future child desires (Not desired)	β	SE	<i>p</i> -value	Odds ration	95% CI	
					Lower	Upper
Fukushima Prefecture (Female): Cox-Snell $R^2 = .21$, Nagelkerke $R^2 = .29$.						
Concerns about radiation effects on a future partner	0.7	0.3	0.006	2.0	1.2	3.4
Neighboring Prefectures (Female): Cox-Snell $R^2 = .26$, Nagelkerke $R^2 = .36$.						
Presence of a person to give advice about radiation	1.5	0.4	0.001	4.4	1.9	10.3
Concerns about radiation effects on a future partner	0.9	0.3	0.001	2.4	1.5	4.1
Other Prefectures (Male): Cox-Snell $R^2 = .19$, Nagelkerke $R^2 = .25$.						
Presence of a person to give advice about radiation	0.9	0.3	0.009	2.4	1.3	4.7
Other Prefectures (Female): Cox-Snell $R^2 = .22$, Nagelkerke $R^2 = .30$.						
Presence of a person to give advice about radiation	0.8	0.3	0.024	2.2	1.1	4.2

Age, marital status, living alone, depressive symptoms, stress, self-esteem, WHO-5, health literacy, and help-seeking were entered as adjustment variables.

Table 4. Multiple regression analysis with childbearing (FPAM) scores as the dependent variable among those desiring to have children in the future.

FPAM: giving birth to a baby	β	SE	<i>s</i> β	<i>p</i> -value	95% CI		VIF
					Lower	Upper	
Fukushima Prefecture (Female): $R^2 = .40$, $aR^2 = .30$.							
(Constant)	11.1	3.1		0.001	4.9	17.2	
Risk perception of radiation health effects: genetic effects	0.9	0.4	0.3	0.036	0.1	1.8	3.7
Self-esteem	-0.2	0.0	-0.4	0.000	-0.3	-0.1	1.5
ATSPPH-SH	-0.1	0.0	-0.2	0.015	-0.2	0.0	1.2
Neighboring Prefectures (Female): $R^2 = .41$, $aR^2 = .31$.							
(Constant)	5.0	2.6		0.054	-0.1	10.2	
WHO-5	0.1	0.0	0.4	0.003	0.0	0.2	2.1
ATSPPH-SH	0.1	0.0	0.3	0.002	0.1	0.2	1.3
Other Prefectures (Male): $R^2 = .45$, $aR^2 = .36$.							
(Constant)	6.1	2.1		0.005	1.9	10.3	
Concerns about radiation effects on a future partner	-0.5	0.1	-0.3	0.001	-0.8	-0.2	1.3
Risk perception of radiation health effects: delayed effects	0.7	0.3	0.3	0.019	0.1	1.3	3.5
WHO-5	0.1	0.0	0.4	0.001	0.0	0.2	2.7
Other Prefectures (Female): $R^2 = .24$, $aR^2 = .15$.							
(Constant)	8.0	2.6		0.003	2.8	13.2	
WHO-5	0.1	0.0	0.3	0.020	0.0	0.2	2.0

aR^2 = adjusted R^2 ; $s\beta$ = standardized partial regression coefficient; SE = standard error.

Age, marital status, living alone, and stress were entered as adjustment variables.

at the time of the nuclear power plant accident affect the desire to have children in the future. Among men in Fukushima Prefecture, women in neighboring prefectures, and men and women in other prefectures, those who had a person with whom they could discuss radiation were more likely to want to have children in the future. Among women in Fukushima and neighboring prefectures, those who wanted to have children in the future were concerned about the effects of radiation on their partners. Among residents of the affected areas of Fukushima

Prefecture, psychological stress was reported to be lower among those who had someone to talk to or seek help from than among those who did not (Horikoshi *et al.*, 2021), suggesting the importance of having someone with whom to discuss radiation. In addition, a 2018 survey of female university students in Fukushima Prefecture reported that those who were concerned about the effects of radiation on their partners were less confident about future childbearing (Ito *et al.*, 2023). Therefore, with regard to women in Fukushima Prefecture, it

Table 5. Multiple regression analysis with child care (FPAM) scores as the dependent variable among those desiring to have children in the future.

FPAM: Caring for a child	β	SE	$s\beta$	p -value	95% CI		VIF
					Lower	Upper	
Neighboring Prefectures (Male): $R^2 = .44$, $aR^2 = .30$.							
(Constant)	−2.1	3.0		0.484	−8.2	3.9	
Presence of a person to give advice about radiation	0.8	0.4	0.2	0.036	0.1	1.6	1.3
Knowledge of radiation	0.7	0.2	0.3	0.003	0.2	1.1	1.2
HL: Communicative	−0.3	0.1	−0.4	0.025	−0.5	0.0	3.0
HL: Critical	0.5	0.2	0.4	0.017	0.1	0.9	3.3
Neighboring Prefectures (Female): $R^2 = .16$, $aR^2 = .03$.							
(Constant)	7.2	3.0		0.017	1.3	13.1	
Knowledge of radiation	−0.6	0.3	−0.2	0.041	−1.2	0.0	1.2
Other Prefectures (Male): $R^2 = .22$, $aR^2 = .10$.							
(Constant)	11.0	2.9		0.000	5.3	16.6	
Self-esteem	−0.1	0.0	−0.3	0.045	−0.2	0.0	2.0
Other Prefectures (Female): $R^2 = .23$, $aR^2 = .14$.							
(Constant)	7.3	2.3		0.002	2.7	11.8	
Presence of a person to give advice about radiation	0.7	0.3	0.2	0.028	0.1	1.3	1.1
Risk perception of radiation health effects: genetic effects	−0.9	0.4	−0.4	0.036	−1.7	−0.1	5.0
HL: Communicative	−0.3	0.1	−0.4	0.002	−0.5	−0.1	3.3
HL: Critical	0.3	0.1	0.3	0.029	0.0	0.6	3.5

^a R^2 = adjusted R^2 ; $s\beta$ = standardized partial regression coefficient; SE = standard error.

Age, marital status, living alone, and stress were entered as adjustment variables.

may be important to provide more information about the effects of radiation on their partners.

Among those with a desire to have children, the results of the present study revealed that factors influencing confidence in future childbearing and child-rearing vary by prefecture and gender. Regarding women in Fukushima Prefecture, those who were more confident about future childbearing were more likely to believe that the health risks to their children and grandchildren from radiation exposure would be low and to be able to consult a mental health professional or other specialist. On the other hand, among women in neighboring prefectures, those who were more confident about future childbearing were less likely to consult a mental health professional. A 2018 survey of female university students in Fukushima Prefecture reported finding no association between confidence in future childbearing and consultation with a mental health professional (Ito *et al.*, 2023). Results vary, but as a region-specific strategy, distributing pamphlets encouraging women in Fukushima to consult a mental health professional or other specialist may be effective in building confidence in childbearing.

Among those who wanted to have a baby, no factors were found to be associated with confidence in future childcare among men or women in Fukushima Prefecture. Among men from neighboring prefectures, those who were more confident about future child-rearing were more likely to have someone to talk to about radiation and to be knowledgeable about radiation. In addition, the more knowledgeable women in nearby prefectures perceived themselves to be about radiation, the higher their confidence in rearing children in the future. The results obtained for Fukushima differ from those in

previous studies (Ito *et al.*, 2023). In a study of female university students in Fukushima Prefecture, their confidence in future child-rearing was associated with a belief that the health risks associated with radiation exposure were low. The factors affecting confidence in future childbearing and child-rearing among those who wanted to have children differed by prefecture and gender, suggesting the need for individualized measures as mentioned above.

This study has three main strengths. First, it reveals the actual status of anxiety about future childbirth and child-rearing at 11 years after the Fukushima Daiichi Nuclear Power Plant accident. Second, the survey covered not only women, but also men. Previous surveys on pregnancy, childbirth, and childcare after the nuclear accident have been limited to women and pregnant women; the actual situation of men has not been clarified. Third, we were able to examine whether the experience of radiation exposure was related to future childbearing intentions.

This study also has some limitations. First, a random sampling of Fukushima Prefecture residents was not possible, so this survey was conducted using an Internet research company. However, the number of registered respondents who were living in Fukushima Prefecture at the time of the nuclear accident was small. As a result, the sample size in Fukushima Prefecture was also small, which resulted in differences in basic attributes. Second, this study did not include any survey items on reproductive health-related factors such as financial status or educational attainment; these items are usually included in studies on pregnancy intention. Moreover, other reproductive health-related factors such as marital relationship and marital duration, which are also typically included in

studies on pregnancy intention, were not surveyed. The influence of these factors should be examined in future research. Third, selection bias was observed, so caution should be exercised in generalizing the survey results. For example, because this survey was conducted using an Internet research company, it is assumed that many of the respondents were interested in the survey topic. In addition, this survey was conducted among those who did not currently have children, and while the survey asked about their confidence in future childbearing and child-rearing, those who were confident about childbearing and child-rearing were the most likely to have already given birth. Therefore, it is possible that a large proportion of the participants in this survey had low confidence in childbearing and child-rearing. Fourth, although this survey was categorized as being associated with Fukushima Prefecture, prefectures near Fukushima, and other prefectures, some areas within Fukushima Prefecture are much closer to the nuclear accident site. Among the prefectures close to Fukushima, Ibaraki Prefecture is closer to the nuclear accident site than are Tochigi and Miyagi Prefectures. Therefore, caution is needed in generalizing the results among the three groups. Finally, the survey did not estimate respondents' radiation doses, and living in Fukushima Prefecture does not necessarily mean that they were exposed to radiation at the time of the disaster. Therefore, the results of this survey can be considered a factor related to the presence or absence of radiation-related support associated with the area of residence at the time of the nuclear accident, and it is difficult to interpret the results as a factor related to the experience of radiation exposure. The study by Bromet *et al.* (Bromet, 2012; Bromet *et al.*, 2011) points out the possibility that not only the experience of exposure, but also the perception of having been exposed to radiation may influence the results, as well as sample selection and educational experience, and thus we need to be cautious in judging whether the results are due to the experience of radiation exposure.

5 Conclusion

The results of this survey revealed that, even at 11 years after the Fukushima Daiichi Nuclear Power Plant accident, anxiety about future childbirth and child-rearing differ by prefecture (Fukushima, neighboring prefectures, and other prefectures) and gender, suggesting a need for group-specific response. In general, however, the proportion of women who were confident about future childbearing was lowest in Fukushima and the confidence was associated with radiation-related risk perceptions in both within and outside Fukushima, suggesting information on radiation-related future childbirth and childcare is also needed outside of Fukushima Prefecture. In addition, the more people want to have children in the future, the more likely they will be able to discuss radiation, and the less likely they will be to believe that radiation has a low impact on their partners; therefore, it is necessary to create an environment where people can openly discuss radiation.

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Conflicts of interest

The authors declare that they have no conflict of interest.

Data availability statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contribution statement

S. Ito: Conceptualization, Methodology, Writing original draft, Investigation.

A. Goto: Supervision, Conceptualization, Editing.

Ethics approval

This study was approved by the Kitasato University School of Nursing Ethics Committee (No. 2021-9-2).

Informed consent

Written informed consent was obtained from all patients and/or families.

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