

Intention to return to the town of Tomioka in residents 7 years after the accident at Fukushima Daiichi Nuclear Power Station: a cross-sectional study

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ABSTRACT

The aim of our study was to identify the factors associated with intention to return (ITR) in residents of Tomioka town, Fukushima Prefecture. We contacted approximated 8000 residents aged 20 years or older who lived in Tomioka. We invited them to take part in a written survey on ITR. In all, 1749 residents' replies were included in the analysis. We asked about ITR in former residents of Tomioka town. We also asked about relevant factors and about risk perception in relation to the health effects of radiation exposure. Of those contacted, 469 (26.8%) had an ITR. Logistic regression analysis revealed that being male (OR = 1.6, 95% CI: 1.24–1.96, $P < 0.001$), the anticipation of improving shopping in the town (OR = 1.5, 95% CI: 1.26–1.67, $P < 0.001$) and requests for individual consultation with experts on the health effects of radiation (OR = 2.7, 95% CI: 2.10–3.48, $P < 0.001$) were associated with the ITR (+), and living with children under 18 years of age (OR = 0.7, 95% CI: 0.51–0.95, $P = 0.023$), reluctance to drink tap water (OR = 0.5, 95% CI: 0.36–0.69, $P < 0.001$) and anxiety regarding genetic effects of radiation in the next generation (OR = 0.6, 95% CI: 0.45–0.79, $P < 0.001$) were associated with the ITR (-) to Tomioka town, independent of other covariates. To allay the anxieties of residents who have an ITR to their hometown, careful risk communication, including information on the potential effects of radiation on health, is important.

Keywords: Fukushima Daiichi Nuclear Power Station; intention to return; radiation; risk perception; Tomioka town

INTRODUCTION

On 11 March 2011, the Great East Japan Earthquake and the resulting tsunami caused severe damage to TEPCO's Fukushima Daiichi Nuclear Power Station (FDNPS), including core meltdowns in the

three reactors and the release of large amounts of radionuclides into the atmosphere [1–3]. To decrease the radiation exposure of residents around the FDNPS, the Governor of Fukushima Prefecture issued instructions at 20:50 on that day for the evacuation of

settlements within 2 km of the FDNPS. At 21:23, the Prime Minister ordered the evacuation of individuals within 3 km of the FDNPS. On 12 March 2011, the evacuation radius was expanded to 20 km [1–7].

The town of Tomioka is located within the region 10–20 km from the FDNPS (Fig. 1). Immediately following the accident, almost all residents of Tomioka were forced to evacuate from their hometown to other areas, mainly Iwaki city and Koriyama city, in the Fukushima Prefecture (Fig. 1). Tomioka was severely damaged by the earthquake and tsunami, and contaminated by radionuclides, including iodine-131 (^{131}I), cesium-134 (^{134}Cs) and cesium-137 (^{137}Cs).

Tomioka's town office led the infrastructure recovery efforts and tedious decontamination process to remove the radiocesium fallout from all areas except in the 'difficult-to-return zone', as designated in November 2011 by the Japanese government. (In Tomioka town, almost 15% of the total area was categorized as a difficult-to-return zone.) In addition, the government provided financial support to residents to speed the reconstruction of their daily lives in Tomioka, including the rebuilding of their houses. On 1 April 2017, the Japanese government lifted the evacuation order for Tomioka;

however, the number of former residents who have returned to their homes remains limited. As at December 2017, only 349 of 13 298 residents (2.6%) have returned to Tomioka. It is speculated that there are many factors associated with residents' hesitation to return, such as insufficient recovery of infrastructure, commercial facilities, and educational institutions for children, as well as insufficient employment in the town. In addition, anxiety about the potential health effects of radiation exposure in Tomioka is considered to be one of the main reasons for residents hesitating to return.

Previously, we investigated the intention to return (ITR) of residents in Kawauchi village, which is located within 30 km of the FDNPS and whose evacuation order was lifted in March 2012 (one year after the accident). As at April 2018, 2197 of 2713 (80.9%) residents had already returned. We found that a lower level of ITR among residents of Kawauchi village was associated with female gender, living in areas with relatively higher ambient doses and expressed anxiety about radiation exposure [8]. In addition, we investigated the risk perception about radiation exposure and its consequent health effects in residents of Kawauchi village and found that more than half of the residents responded that they had anxiety about the health effects of radiation on children. Almost half of all

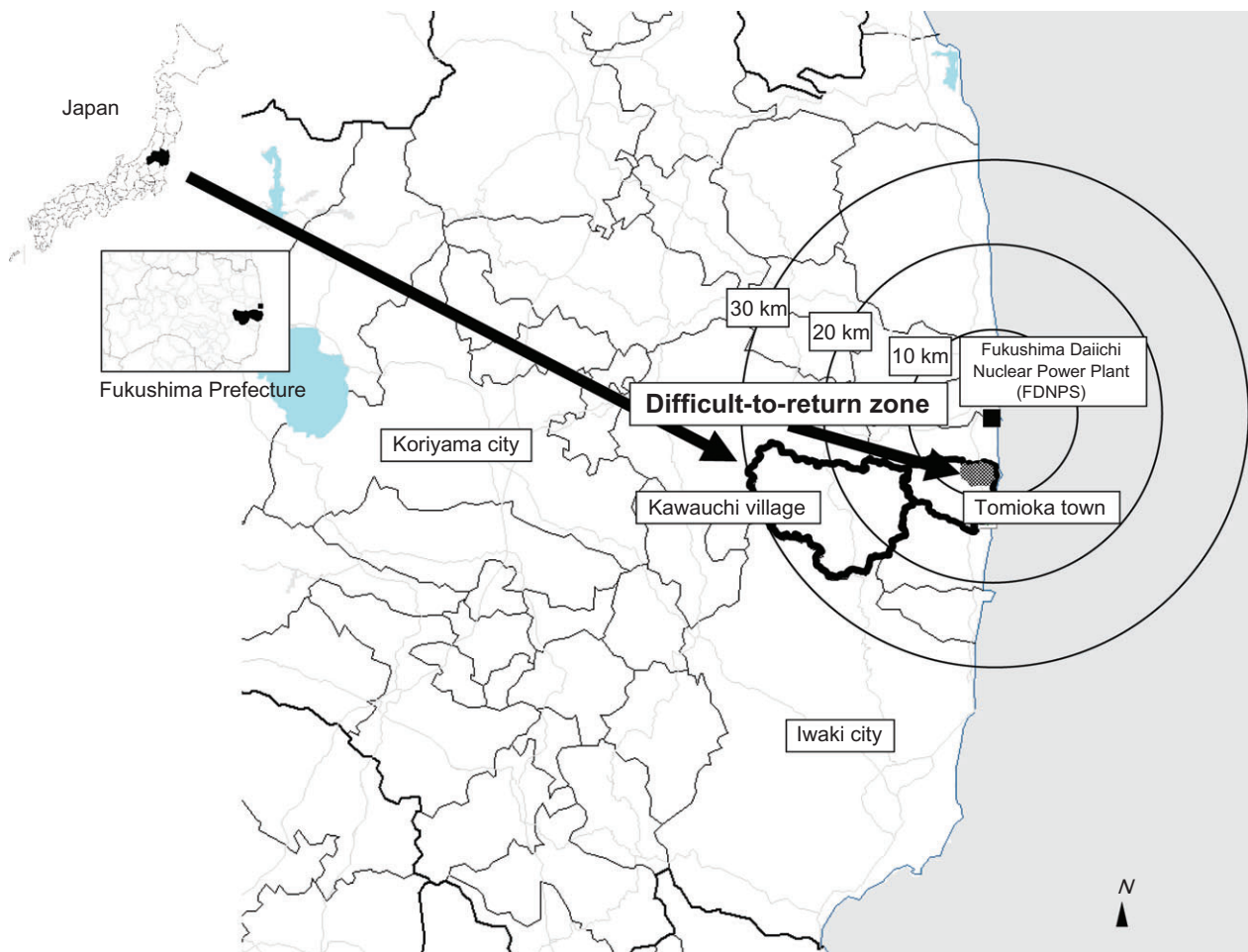


Fig 1. Locations of Tomioka town, Kawauchi village and the Fukushima Dai-ichi Nuclear Power Station.

residents indicated that they had anxiety about the health effects of radiation in the next generation [9]. Recently, Takebayashi *et al.* pointed out that radiation-related anxiety was related to the intent to leave employment or to not return home, and they reported a positive relationship between risk perception and an intention not to return home in a study of residents in the evacuation order area [10]. To promote the recovery of Tomioka, it is important to clarify the factors associated with residents' ITR to the town and their risk perceptions related to radiation and its consequent health effects.

In this study, we conducted research to identify the factors associated with the ITR to Tomioka and to clarify the perceptions about the risk of health effects from radiation exposure among residents. In addition, we compared the risk perception of the former residents of Tomioka with that of the people of Kawauchi village [9, 11].

METHODS

Study setting

The study was conducted in the town of Tomioka in Fukushima Prefecture in August and September 2017. The subjects of this study were the former residents of Tomioka town who had held resident cards on 1 March 2011 for the zones of Tomioka to which people were permitted to return. Among such former residents, those who still hold a resident card for the town were invited to participate in this study. We sent questionnaires by regular mail, and posted notices in the public relations magazine issued by the Tomioka town office. In all, ~8000 former residents aged 20 years of age or older were invited to participate. We obtained responses from 2185 former residents (27.3%), and after excluding 436 for incomplete responses, we included 1749 of the former residents (882 men and 867 women) in the analysis.

Data collection

The questionnaire for this study was developed based on: our previous studies of the residents of Kawauchi village in 2014 [9], the mental health and lifestyle survey within the framework of the Fukushima Health Management Survey [12], and questions and answers that we published for the residents of Fukushima Prefecture after the accident [13]. Also, we revised the questionnaire after discussion with staff members of Tomioka's town office. The results of the study are to be conveyed to the residents.

In the questionnaire, we asked residents about their ITR within the 3 years following the lifting of the evacuation order of Tomioka town. We defined ITR (+) as residents who intend to return to Tomioka within the 3 years following the lifting of the evacuation order or who have already returned, and ITR (-) as residents who do not intend to return to Tomioka within the 3 years following the lifting of the evacuation order. In addition, we collected data on demographic variables, including sex, age, whether living with children who are under 18 years of age, and social factors (including a perceived need for shopping and educational facilities in Tomioka). We asked residents whether they were reluctant to eat foodstuff collected in Tomioka, drink tap water in Tomioka, and whether they want to consult with radiation experts. We also asked questions to evaluate the risk perception of residents about the potential health effects of radiation exposure, such as acute radiation syndrome, the

risk of cancer in themselves or their children, and genetic effects in the next generation caused by living in Tomioka.

Statistical analyses

Answers were divided into two categories: 'yes' and 'probably yes' as 'YES', and 'no' or 'probably no' as 'NO.' We divided age into two categories: <60 years and ≥60 years. To assess participants' risk perception, we compared the results for Tomioka's residents with those for Kawauchi's residents in 2017. In Kawauchi village, we asked 789 residents the same questions as those we asked in Tomioka, and 402 residents responded. After excluding the questionnaires of 48 residents due to incomplete answers, the questionnaires of 354 residents (175 men and 179 women) from Kawauchi were included for comparison purposes.

We identified the factors associated with the ITR using a chi-square test, and the factors associated with the ITR independent of other covariates using logistic regression analysis. Factors that were significantly associated with ITR as determined by the chi-square test were selected in the logistic regression analysis. We excluded statistically confounding factors, then included in the model: sex, age, hospital attendance history, living with children under the age of 18, anticipation of improved shopping facilities, reluctance to drink tap water, anxiety about possible genetic effects in the next generation, and consultation requests with radiation experts. *P*-values of <0.05 were considered significant. Statistical analysis was performed using IBM SPSS Statistics Version 19 software (SPSS Japan, Tokyo).

Ethics approval

The study was approved by the ethics committee of Nagasaki University Graduate School of Biomedical Sciences. Prior to the study, we obtained permission from the city's municipal government of Tomioka to implement the study.

RESULTS

The characteristics of the subjects are summarized in Table 1. A total of 469 of 1749 residents (26.8%) were found to be ITR (+), and 1280 (73.2%) were found to be ITR (-). Table 2 shows the demographic characteristics of ITR (+) and ITR (-) residents. Overall, 320 ITR (+) residents and 758 ITR (-) residents were ≥60 years of age, respectively (68.2 vs 59.2%, *P* < 0.001). In addition, 70 ITR (+) residents and 284 ITR (-) residents were living with children under 18 years of age (14.9% vs 22.2%, *P* < 0.001). Significantly more males were ITR (+) than ITR (-) (60.3% vs 46.8%, *P* < 0.001). In terms of residents reporting that shopping facilities would be useful in Tomioka, there were 172 in the ITR (+) group and 282 in the ITR (-) group, respectively (36.7% vs 22.2%, *P* < 0.001), and 98 ITR (+) and 155 ITR (-) (20.9% vs 12.1%, *P* < 0.001) residents believed that educational facilities for children would be useful in Tomioka. In addition, 178 ITR (+) and 280 ITR (-), respectively (38.0% vs 21.9%, *P* < 0.001), wanted to consult with a radiation expert.

Table 3 shows the risk perception concerning radiation exposure in ITR (+) and ITR (-) residents. The ratios of residents who felt anxiety about the consumption of local foodstuffs and tap water

Table 1. Basic characteristics of the subjects

	Number	%
Sex		
male	882	50.4
Female	867	49.6
Age		
20s	99	5.7
30s	127	7.3
40s	161	9.2
50s	284	16.2
60s	561	32.1
70s	305	17.4
80s over	212	12.1
Do you regularly visit a hospital(s)?		
Yes	1221	69.8
No	528	30.2
Are you living with children under 18 years old?		
Yes	354	20.2
No	1395	79.8
Do you have ITR within 3 years after the lifting of the evacuation order of Tomioka?		
Yes	469	26.8
No	1280	73.2
Do you think that shopping facilities will be useful in Tomioka?		
Yes	454	26.0
No	1295	74.0
Do you think that educational facilities for children will be useful in Tomioka?		
Yes	253	14.5
No	1496	85.5
Do you want to consult with radiation experts?		
Yes	458	26.2
No	1291	73.8
Are you reluctant to eat foodstuff collected in Tomioka?		

Continued

Table 1. Continued

	Number	%
Yes	1397	79.9
No	352	20.1
Are you reluctant to drink tap water in Tomioka?		
Yes	1445	82.6
No	304	17.4
Do you think that acute radiation syndrome will occur if you live in Tomioka?		
Yes	636	36.4
No	1113	63.6
Do you think that cancer will occur if you live in Tomioka?		
Yes	1176	67.2
No	573	32.8
Do you think that cancer will occur if children live in Tomioka?		
Yes	1358	77.6
No	391	22.4
Do you think that genetic effects will occur to the next generation in Tomioka?		
Yes	1255	71.8
No	494	28.2

were higher in ITR (-) than in ITR (+) former residents. In addition, more ITR (-) than ITR (+) former residents reported they believed that late health and genetic effects would occur if they (or their children) lived in Tomioka.

Logistic regression analysis revealed that being male (OR = 1.6, 95% CI: 1.24–1.96, $P < 0.001$), the anticipation of improving shopping in the town (OR = 1.5, 95% CI: 1.26–1.67, $P < 0.001$) and requests for individual consultation with experts on the health effects of radiation (OR = 2.7, 95% CI: 2.10–3.48, $P < 0.001$) were associated with the ITR (+), and living with children under 18 years of age (OR = 0.7, 95% CI: 0.51–0.95, $P = 0.023$), reluctance to drink tap water (OR = 0.5, 95% CI: 0.36–0.69, $P < 0.001$) and anxiety regarding genetic effects of radiation in the next generation (OR = 0.6, 95% CI: 0.45–0.79, $P < 0.001$) were associated with the ITR (-) to Tomioka town, independent of other covariates (Table 4).

Then, we compared the risk perceptions in Tomioka town and Kawauchi village. Compared with the residents of Kawauchi village, significantly more of Tomioka's residents were concerned about the risk of cancer in themselves and in children, and about genetic

Table 2. Demographics of residents with ITR (+) and ITR (-)

	ITR (+)		ITR (-)		P-value
	(n = 469)		(n = 1,280)		
	Number	(%)	Number	(%)	
Are you a male?	283 ^a	(60.3)	599 ^a	(46.8)	<0.001
Are you 60 years of age or older?	320	(68.2)	758	(59.2)	<0.001
Do you regularly visit a hospital(s)?	345	(73.6)	876	(68.4)	0.04
Are you living with children under 18 years of age?	70	(14.9)	284	(22.2)	<0.001
Do you think that shopping facilities will be useful in Tomioka?	172	(36.7)	282	(22.2)	<0.001
Do you think that educational facilities for children will be useful in Tomioka?	98	(20.9)	155	(12.1)	<0.001
Do you want to consult with radiation experts?	178	(38.0)	280	(21.9)	<0.001

^aNumber of residents who answered 'Yes'.

Table 3. Risk perceptions of the health effects of radiation exposure among Tomioka residents

	ITR (+)		ITR (-)		P-value
	(n = 469)		(n = 1280)		
	Number	(%)	Number	(%)	
Are you reluctant to eat food from Tomioka?	325 ^a	(69.3)	1072 ^a	(83.8)	<0.001
Are you reluctant to drink the tap water in Tomioka?	332	(70.8)	1113	(87.0)	<0.001
Do you think that acute radiation syndrome will occur if you live in Tomioka?	122	(26.0)	514	(40.2)	<0.001
Do you think that cancer will occur if you live in Tomioka?	237	(50.5)	939	(73.4)	<0.001
Do you think that cancer will occur if children live in Tomioka?	309	(65.9)	1049	(82.0)	<0.001
Do you think that genetic effects will occur in the next generation in Tomioka?	283	(60.3)	972	(75.9)	<0.001

^aNumber of residents who answered 'YES'

Table 4. Logistic regression analyses for ITR among Tomioka residents

Variables	References	OR	95%CI
Sex	Female (ref)/male	1.6**	1.24–1.96
Age	<60 (ref)/>_60 years	0.8	0.65–1.11
Hospital attendance situation	No (ref)/Yes	1.1	0.85–1.47
Living with children under 18 years of age	No (ref)/Yes	0.7*	0.51–0.95
Anticipation of improving shopping in the town	No (ref)/Yes	1.5**	1.26–1.67
Reluctance to drink tap water	No (ref)/Yes	0.5**	0.36–0.69
Anxiety about genetic effects in the next generation of radiation exposure	No (ref)/Yes	0.6**	0.45–0.79
Requests for individual consultation with experts on the health effects of radiation	No (ref)/Yes	2.7**	2.10–3.48

^aOR = odds ratio, CI = confidence interval, *P < 0.05, **P < 0.01.

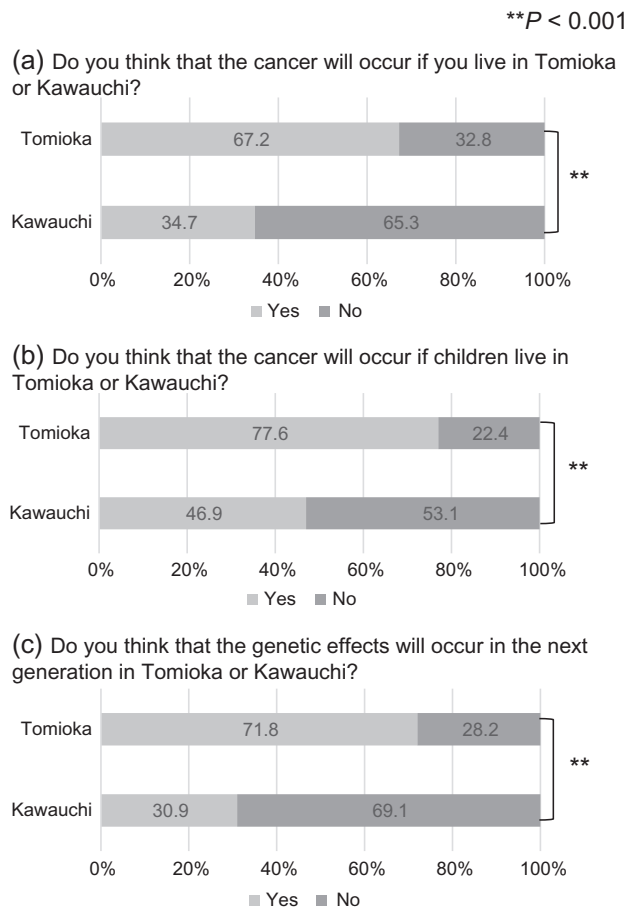


Fig. 2. Residents' risk perceptions of the health effects of radiation in Tomioka town and Kawauchi village. (a) 'Do you think that cancer will occur if you live in Tomioka or Kawauchi?' (b) 'Do you think that cancer will occur if children live in Tomioka or Kawauchi?' (c) 'Do you think that genetic effects will occur in the next generation in Tomioka or Kawauchi?'

effects in the next generation, if they were to return to Tomioka town (Fig. 2). Specifically, 67.2% of former residents of Tomioka reported that they were concerned that cancer would occur in themselves, 77.6% were concerned that such effects would occur in children, and 71.8% were concerned that genetic effects would occur in the next generation as a result of living in the town.

DISCUSSION

We conducted this study in 2012 to clarify the factors that are associated with ITR in Kawauchi village, which lifted its evacuation order in 2012, and we found female sex, living in areas with relatively higher ambient doses, and expression of anxiety about radiation exposure were independently associated with ITR (-) in Kawauchi [9]. These results suggested the importance of active participation by scientists and local authorities in communicating actual risks to the general population involved in returning home.

In our current study, we showed that being male, the anticipation of improving shopping in the town and requests for individual consultation with experts on the health effects of radiation were associated with the ITR (+), and living with children under 18 years of age, reluctance to drink tap water and anxiety about genetic effects in the next generation of radiation exposure were associated with the ITR (-) to Tomioka town, independent of other covariates.

We found that the residents who had higher levels of anticipation for improved shopping and educational facilities had higher levels of ITR to Tomioka. In the devastation that follows a major disaster, there is a need for multiple sectors to unite and devote new resources for supporting the rebuilding of infrastructure, the provision of health and social services, the restoration of care delivery systems, and other critical recovery needs [14]. In Tomioka, a new medical clinic and a new supermarket have been opened, and the elementary and junior high schools are scheduled to re-open in April 2018. On the other hand, the high school is still closed, and hospitals equipped with beds have not yet re-opened. Further rebuilding of infrastructure will be necessary for the smooth return of the residents.

We showed that residents over the age of 60 years had a higher ITR, whereas female residents and those people living with children under 18 years of age had a lower ITR. These findings suggest that residents who have children, especially mothers, have anxieties about the health effects of radiation on their children, making them hesitant to return to Tomioka. It is well known that after the Chernobyl disaster, a significant increase in thyroid cancer was reported among children and adolescents exposed to radioactive iodine released at the time of the accident in Belarus, Russia, and the Ukraine [15]. After the accident at the FDNPS, many parents, especially the mothers of Fukushima Prefecture who had young children, were worried about effects on their children's health, especially thyroid diseases, such as cancer. In order to provide scientific clarification regarding potential medical effects, and to allay the anxiety of Fukushima's residents, thyroid ultrasound screening is being done within the framework of the Fukushima Health Management Survey, targeting all residents who were younger than 18 years of age at the time of the accident (~360 000 individuals). The first screening cycle, carried out from October 2011 to March 2014, identified 113 confirmed or suspected thyroid malignancies among 300 476 screened individuals; the second screening cycle, carried out from April 2014 to March 2016, identified 71 confirmed or suspected thyroid malignancies among 270 516 screened individuals [16]. Although the diagnosis of a number of thyroid cases from Fukushima is considered to be an effect of the screening, using modern, highly sensitive ultrasound technology [6, 16, 17], many residents of Tomioka town still have anxieties, which might be underlying their hesitation to return to their hometown. To allay the anxiety of residents who have an ITR to Tomioka, careful risk communication about the potential effects of the radiation on their health is important.

We also found that residents' reluctance to drink tap water in Tomioka was associated with ITR, independent of other covariates. In the initial phase of the accident, a screening of the tap water was conducted, and a level of ^{131}I exceeding provisional regulation values was detected in several prefectures, including the Tokyo Metropolitan prefecture, as well as in Fukushima Prefecture [18].

On the other hand, radiocesium, such as ^{134}Cs and ^{137}Cs , has not been detected in the tap water in Fukushima Prefecture, as radiocesium is easily filtered out. Nevertheless, residents still have anxiety about the water safety because they remember the water contamination by radioiodine (not radiocesium) in the initial phase of the accident. Careful explanation, including an explanation of the mechanism for filtering radiocesium from water, is essential for residents who have the ITR to Tomioka. Further, we found that residents' reluctance to consume foods from Tomioka was also associated with ITR. It is well known that radiocesium is concentrated in wild mushrooms and wild animals, such as wild boars [19–21]. Before the accident, areas around the FDNPS were famous for their wild mushrooms. Because the collection and consumption of wild mushrooms is a part of the culture of this area, its residents are keenly interested in the radiocesium levels of the wild mushrooms. In Kawauchi village, we confirmed that radiocesium was still detectable in most samples [19–21]. Although the committed effective doses are relatively limited, continuous monitoring of the active concentrations of radiocesium in mushrooms and related risk communication to residents in Fukushima is needed for sustained recovery from the nuclear disaster.

In 2014, Fukushima Prefecture investigated the risk perception of evacuees within the framework of the Fukushima Health Management Survey and reported that 31.4% believed that health effects would occur in children, and that 38.0% believed that genetic effects would occur in future generations [12]. In our current study, we distributed a similar questionnaire to residents of Kawauchi village in 2017: 46.9% believed that health effects would occur in children, and 30.9% believed that genetic effects would occur in future generations. On the other hand, in residents of Tomioka, 77.6% of residents believed that health effects would occur in children as a result of living in Tomioka, and 71.8% of residents believed that genetic effects would occur in future generations as a result of living in the town. These results suggested that many residents have anxieties about the health status of children and of the next generation as a result of residing in Tomioka. Since the accident, scientists have made many efforts to communicate with residents regarding the effects of radiation exposure on the health of the children and of the next generation. In 2014, we evaluated the risk perception of residents in Kawauchi village and showed that almost half residents had anxieties about the genetic effects of radiation in future generations [9]. Suzuki *et al.* assessed the relationship between the perception of radiation risks and the level of psychological distress among evacuees in Fukushima and showed that concern about radiation risk was associated with psychological distress [22]. Recently, Miura *et al.* also examined the association between perceived radiation risk and other factors at baseline and mid-term mental health after the accident and suggested that female evacuees who believed that their health was substantially affected by the nuclear disaster were at an increased risk of having poor mid-term mental health [23]. We need to carefully evaluate the mental health status of residents of Tomioka to develop appropriate interventions.

In this study, the response rate was relatively low, which might have led to selective responding. In this study, 2185 former residents responded to our study, but 436 of them (20.0%) returned incomplete replies, which suggests that the questionnaire was not

easy to complete correctly. We could not obtain sufficient information on potential confounding factors, such as detailed lifestyle habits and economic and educational status. Further, we could not evaluate the radiation exposure doses in each resident. Since the current study is cross-sectional in its design, we could not evaluate the causal nature of the findings. Further evaluations, including in-depth assessments, and especially mental health assessments, are needed to promote the recovery of local communities after the nuclear disaster.

In conclusion, we identified the factors associated with the ITR in residents of Tomioka town, Fukushima Prefecture. Nearly 8 years have passed since the accident at the FDNPS. Scientists should cooperate with residents and local authorities to ensure the recovery of communities from the nuclear disaster.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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