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The relationship between geographical region and perceptions of radiation risk after the Fukushima accident: The mediational role of knowledge

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Abstract

Since the Fukushima accident, radiation risk perception has been of public concern. Factors related to regional differences in radiation risk perception and the role that knowledge of radiation effects plays are still not clearly understood. Here, we first assessed the validity of the Lindell radiation risk perception scale by comparing it with the mortality rate of traffic accidents. We then investigated the relationship between the perceptions and both the geographical regions and the knowledge of genetic effects and, further, verified the mediating role of knowledge in the perception. The sample comprised 832 participants who responded to an online questionnaire in August 2018, from Tokyo and Fukushima. There was a significant association between the Lindell scale and the perceived magnitude of genetic risk relative to traffic accident mortality. Knowledge of genetic effects after the atomic bombs was associated with perceptions of lower genetic risks. The relationship between geographical region and risk perception was mediated by knowledge. However, approximately 40% of those who had knowledge still perceived a high risk, indicating that perception is not governed by knowledge alone. In addition to efforts to share knowledge, it is important to interactively communicate regarding risk to alleviate the anxiety felt by individuals.

Keywords

accident/ nuclear/ radiation risk/ social impact/ risk communication

1. Introduction

Concerns over the risk of radiation to public health rose sharply following the March 2011 Fukushima Daiichi Nuclear Power Station (FDNPS) accident caused by the Great East Japan Earthquake. Fortunately, a United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) publication in 2014 reported that the radiation levels at the Fukushima accident were much lower than those during the Chernobyl accident and that there was no discernible increase in the incidence of radiation-related health effects, including heritable effects and cancer (UNSCEAR, 2014). Furthermore, it was suggested that the more serious risks were to people's mental health and well-being (UNSCEAR, 2014; Murakami et al., 2018b), and the psychological health impacts have indeed been exacerbated by the distribution of confusing health information (Ohto et al., 2017).

Methods of information acquisition after a disaster play an important role in perceived risk and decision-making. Distrust of the government and the uncertain effects of low-dose radiation were the major factors in parental anxiety (Tateno and Yokoyama, 2013) and resulted in, for example, the avoidance of foods and products made in Fukushima and voluntary restraints on travel there (Sekiya, 2016; Mitsubishi Research Institute Inc., 2017). Individuals who receive information from the mass media and the Internet must carefully examine the reliability of their information sources, and previous studies reported that those who actively gather information are likely to experience higher radiation anxiety and those who receive information from experts experience lower anxiety (Suzuki, 2014; Hino et al., 2016). It is therefore likely that reliable information obtained from specialized sources—especially knowledge from international organizations—could reduce people's perceptions of radiation risk. Furthermore, since it has been pointed out that the relationship between subjective knowledge and risk perception or anxiety after the Fukushima accident was inconsistent among studies (Takebayashi et al., 2017), it is necessary to examine the role of knowledge.

The perception of higher radiation risks, especially regarding genetic effects, was related to psychological distress (Suzuki et al., 2015), stigma, and discrimination, such as bullying due to radiation (Sawano et al., 2018; Oe et al., 2019). Of the various indicators of radiation risk perception, the Lindell scale (Lindell and Barnes, 1986) regarding genetic effects has been widely used following the Fukushima accident (Takebayashi et al., 2017). According to a survey using the scale conducted in fiscal year (FY; from April to March) 2017 in Fukushima Prefecture (Fukushima Health Management Survey [FHMS]), 37.2% of respondents reported that they believed it was 'very likely' or 'likely' that radiation exposure leads to genetic effects (Fukushima Prefecture, 2019). According to the FY 2011 survey, 60.2% of respondents reported that the probability of radiation exposure leading to genetic effects was likely or very likely. Although the percentage decreased year by year until FY 2014 (38.0%), it has remained almost unchanged since then (Fukushima Prefecture, 2019). In contrast, according to a survey conducted by Mitsubishi Research Institute with Tokyo residents, 49.8% of respondents answered that genetic effects were 'very likely' or 'likely' (Mitsubishi Research Institute Inc., 2017). However, the factors related to these differences in perceptions of radiation risk between the geographical regions are still not clearly understood, including any role played by knowledge.

Furthermore, the Lindell measurement scale is a single item, and its validity has not been clarified.

The present study had three objectives. First, we validated the Lindell scale of radiation risk perception by comparing it with the perceived magnitude of radiation risk relative to traffic accident mortality rates. Second, we investigated the relationship between geographical regions, knowledge of genetic effects, and perception of radiation risks. Third, we sought to verify the mediating role of knowledge on the perception of radiation risk.

2. Methods

2.1. Study participants

An online survey was conducted with 832 participants (416 from Tokyo and 416 from Fukushima) who had registered as survey panelists with Macromill Co., Ltd. The survey was completed on August 25–26, 2018, by members of the public aged from 20 to 59 years. The company set a target number of participants in each prefecture, grouped by sex and age. The ratios of sex and age were adapted to the following demographic dynamics of each prefecture: Fukushima—men: 52%; women: 48%; 20s: 19%; 30s: 25%; 40s: 27%; 50s: 29%; Tokyo—men: 51%; women: 49%; 20s: 22%; 30s: 27%; 40s: 29%; 50s: 22%. The company then asked registered members to respond to the questionnaires until these target numbers of participants were obtained. The geographical locations of Fukushima and Tokyo are shown in Figure 1. We previously reported relationships between perceptions of genetic risk, mindfulness, health anxiety, and psychological distress using the same survey (Kashiwazaki et al., 2020).

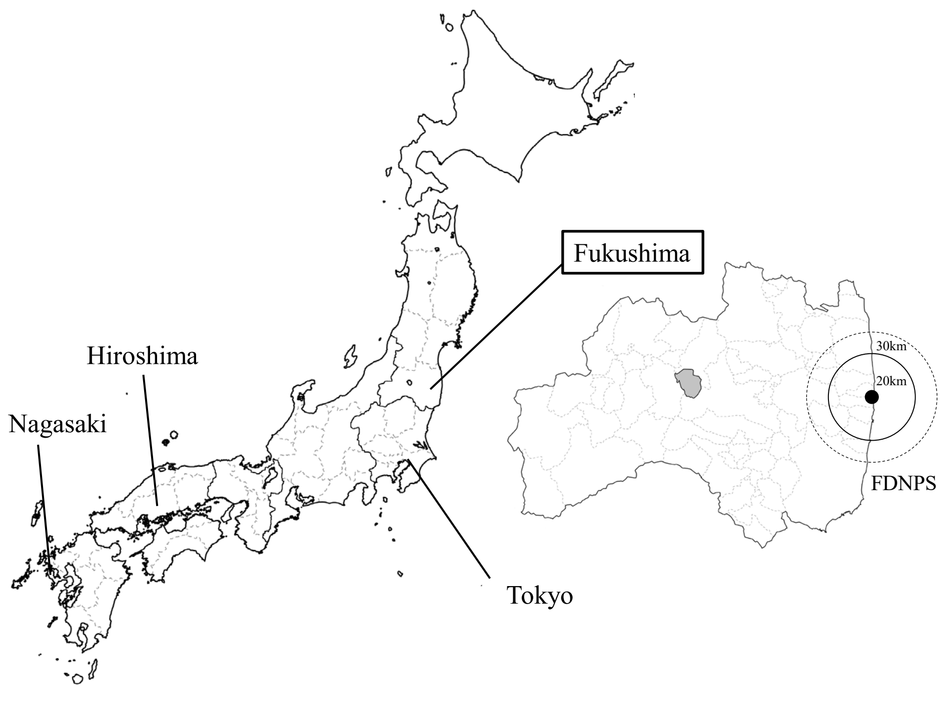

Figure 1. Geographical locations of Fukushima and Tokyo.

2.2. Question items

The perception of genetic risk—The Lindell scale—was assessed by the question ‘What do you think is the likelihood that the health of future (i.e., as-yet unborn) children and grandchildren will be affected as a result of the current level of radiation exposure [in Fukushima]?’ and measured on a four-point Likert scale ranging from ‘very likely’ to ‘very unlikely.’ This questionnaire was developed in a previous study (Lindell and Barnes, 1986) and has been used in many studies following the Fukushima accident (Suzuki et al., 2015; Takebayashi et al., 2017; Murakami et al., 2018a). For Tokyo respondents, ‘in Fukushima’ was added to the questionnaire.

We then asked the participants to assess the perceived magnitude of genetic risks from radiation exposure from the Fukushima accident relative to the traffic accident mortality rate (perceived magnitude of genetic risk relative to the traffic accident mortality rate). The question was as follows: ‘In order to grasp the magnitude of the health effects [in Fukushima] on people in the next generation and beyond (i.e. children, grandchildren), please think in terms of mortality from traffic accidents. How much do you think the current exposure to radiation has the potential to affect the health of people of the next generation and beyond [in Fukushima], compared to the potential for death in traffic accidents? Please choose the closest answer.’ Answers were limited to four options: ‘higher,’ ‘about the same,’ ‘about 1/10,’ and ‘1/100 or less.’ We used the traffic accident mortality rate because this has often been used as a reference indicator to assess the perceived magnitude of risk (Lichtenstein et al., 1978). According to an International Conference on Radiological Protection report, the genetic effect on humans of 1 Gy of radiation exposure is conservatively estimated at 20 per 10,000, or 0.2% (ICRP, 2007). The estimated additional exposure dose for the people affected by the Fukushima accident was approximately 20 mSv (UNSCEAR, 2014). The genetic effect is therefore estimated to be 0.004% or less, although it should be noted that this value is conservatively overestimated from a radiological protection viewpoint. Since the annual traffic accident mortality rate in Japan in 2017 was 0.4% (Ministry of Health, Labor and Welfare, 2018), any response other than ‘1/100 or less’ was considered an overestimation.

Regarding our knowledge of genetic effects, we first introduced the findings of the UNSCEAR report [1] as follows: “In a report released by UNSCEAR, it was stated that no health effects have resulted from radiation exposure to the atomic bombs according to several studies, including in the offspring of survivors. Furthermore, because the dose level among the people of Fukushima Prefecture due to the nuclear accident was lower than those due to the atomic bombing in Hiroshima and Nagasaki, no increase in health effects in offspring is expected as a result of the Fukushima accident.” We then asked the participants the following questions, in order to assess two types of knowledge of genetic effects: ‘Did you know that no health effects have resulted from radiation exposure to the atomic bombs according to several studies, including in the offspring of survivors?’ (knowledge of genetic effects after the A-bombs) and ‘Did you know that no increase in health effects in offspring is expected as a result of the Fukushima accident?’ (knowledge of genetic effects after the Fukushima accident). The responses were measured using three options (‘I knew,’ ‘I’ve heard,’ and ‘I didn’t know’). The questionnaires used in this study asked the participants whether or not they knew about the texts on genetic effects related to radiation above, and included partially subjective judgments.

We also asked the participants to provide information on other covariates, including sex, age, education, occupation, and trusted sources of information, because they have been associated with radiation risk perception (Takebayashi et al., 2017).

2.3. Statistical analysis

First, a χ^2 test for trends was used to compare the mortality rate of traffic accidents in Japan to confirm the validity of the scale of perception of genetic risk. The perception of genetic risk was classified into two categories (high: very likely and likely; low: very unlikely and unlikely) in accordance with previous studies (Takebayashi et al., 2017; Murakami et al., 2018a). A previous study has shown that there is no significant difference between geographical region and risk perception for this questionnaire (Kashiwazaki et al., 2020), but that study used t-tests and regarded the value of risk perception as a continuous variable, because the purpose of the study was not to investigate a difference in perceptions of genetic risk in geographical regions but to analyze the relationship between mindfulness, health anxiety, perception of genetic risk, and psychological distress using structural equation modeling.

For more detailed analysis, this study employed χ^2 tests to investigate the associations between perceptions of genetic risk and the different geographical regions, other socio-demographic variables, knowledge, and trusted sources of information. We also investigated the associations between different geographical regions and knowledge, and a binomial logistic regression analysis was then performed. Model 1 used geographical region as an explanatory variable and the perception of genetic risk as an objective variable. In Model 2, knowledge of genetic effects after the A-bombs was added as an explanatory variable to investigate the role of knowledge as a mediator by comparing the results with Model 1. Knowledge of genetic effects after the A-bombs was added as the explanatory variable, because this variable showed significant associations with both geographic regions and perceptions of genetic risk (see Results). Since other socio-demographic variables, excluding geographic regions and trusted sources of information, were not significantly associated with perceptions of genetic risk, these variables were not included as covariates in the logistic regression analyses.

All statistical procedures were performed using SPSS for Windows (version 25; IBM, Chicago, USA) with a 0.05 significance level. Ethical approval for the study was granted by the Fukushima Medical University Ethics Committee (authorization No. General 30016).

3. Results

The distribution of the basic characteristics and trusted sources of information by geographical region is presented in Table 1. There were no regional differences in sex and age. The distributions of the highest level of education and occupation were significantly different between Tokyo and Fukushima: the proportions of junior or high school graduates in our study were 44.5% in Fukushima and 16.8%

in Tokyo, which are almost equal to or slightly lower than the actual values in the prefectures (Fukushima 61.3%, Tokyo 23.3%) (Statistics Bureau of Japan, 2012). Trusted sources of information were also significantly different between Fukushima and Tokyo. Fukushima participants regarded local press, public relations by local governments, and briefing sessions by central and local governments as more trusted sources of information than Tokyo participants.

Table 1. Demographic characteristics and trusted sources of information among Fukushima and Tokyo participants. Relationships between sex, age, highest level of education, occupation, and geographical regions are from a previous study (Kashiwazaki et al., 2020).

	Total		Fukushima		Tokyo			
	n (%)		n (%)		n (%)		χ^2	
Sex								
Men	427	(51.3)	215	(51.7)	212	(51.0)	0.043	
Women	405	(48.7)	201	(48.3)	204	(49.0)		
Age								
20s	169	(20.3)	78	(18.8)	91	(21.9)	6.250	
30s	214	(25.7)	102	(24.5)	112	(26.9)		
40s	236	(28.4)	114	(27.4)	122	(29.3)		
50s	213	(25.6)	122	(29.3)	91	(21.9)		
Highest level of education								
Junior or high school graduate	255	(30.6)	185	(44.5)	70	(16.8)	74.783	***
University etc. graduate	577	(69.4)	231	(55.5)	346	(83.2)		
Occupation								
Employee etc.[a]	465	(55.9)	212	(51.0)	253	(60.8)	8.205	*
Self-employed etc.[b]	48	(5.8)	27	(6.5)	21	(5.0)		
Other[c]	319	(38.3)	177	(42.5)	142	(34.1)		
Trusted source of information								
National press	323	(38.8)	168	(40.4)	155	(37.3)	0.855	
Local press	220	(26.4)	162	(38.9)	58	(13.9)	66.837	***
Magazines	48	(5.8)	22	(5.3)	26	(6.3)	0.354	
Announcement by central governments	165	(19.8)	75	(18.0)	90	(21.6)	1.701	
Announcement by international organizations	176	(21.2)	69	(16.6)	107	(25.7)	10.406	**
Public relations by local governments	140	(16.8)	96	(23.1)	44	(10.6)	23.222	***
Briefing sessions by the central & local governments	83	(10.0)	52	(12.5)	31	(7.5)	5.902	*
Doctors & stakeholders	209	(25.1)	105	(25.2)	104	(25.0)	0.006	
Information heard from experts	201	(24.2)	95	(22.8)	106	(25.5)	0.794	
Books written by experts	114	(13.7)	47	(11.3)	67	(16.1)	4.066	*
Information from families and acquaintances in the prefecture	62	(7.5)	36	(8.7)	26	(6.3)	1.743	
Information from families and acquaintances outside the prefecture	23	(2.8)	11	(2.6)	12	(2.9)	0.450	
Online information from experts	138	(16.6)	57	(13.7)	81	(19.5)	5.004	*
Online information from non-experts	45	(5.4)	17	(4.1)	28	(6.7)	2.843	
Do not trust any of above	225	(27.0)	111	(26.7)	114	(27.4)	0.055	

* p <0.05, ** p <0.01, *** p <0.001

[a] Company employee, civil servant, non-profit-organization employee, teacher, health professional, and other professionals.

[b] Agriculture, forestry, and fisheries workers and other self-employed workers.

[c] Part-time or casual worker, working on the side, housewife/husband, university student, technical college student, junior college student, preparatory school student, jobless, retired, etc.

Table 2 compares the perception of genetic risks and the perceived magnitude of those risks relative to traffic accident mortality rates. There were significant associations between the two indicators, irrespective of geographical region: 86.9% of the group that perceived high genetic risks overestimated the relative risk, while only 62.0% of those that perceived low genetic risks did so. Those who answered it was "(very) unlikely" showed a significantly lower perceived magnitude of genetic risk relative to traffic accident mortality rates (38.0% for "1/100 or less") than those who answered that they could be "(very) likely" (13.1%).

Table 2. Relative perceptions of genetic risk and traffic accident mortality rates.

	Perceived magnitude of genetic risk relative to traffic accident mortality rates									
	higher		about the same		about 1/10		1/100 or less			
Perception of genetic risk (The Lindell scale)	n	(%)	n	(%)	n	(%)	n	(%)	χ^2	
Total										
(Very) Unlikely	35	(10.0)	80	(22.9)	102	(29.1)	133	(38.0)	91.205	***
(Very) Likely	135	(28.0)	160	(33.2)	124	(25.7)	63	(13.1)		
Fukushima										
(Very) Unlikely	21	(11.1)	40	(21.2)	52	(27.5)	76	(40.2)	43.565	***
(Very) Likely	59	(26.0)	78	(34.4)	59	(26.0)	31	(13.7)		
Tokyo										
(Very) Unlikely	14	(8.7)	40	(24.8)	50	(31.1)	57	(35.4)	46.453	***
(Very) Likely	76	(29.8)	82	(33.2)	65	(25.5)	32	(12.5)		

***p<.001

Table 3 shows the relationship between socio-demographic variables, knowledge, trusted sources of information, and perceptions of genetic risk. The proportion of those perceiving high genetic risk was 54.6% in Fukushima, which was significantly lower than the 61.3% in Tokyo (χ^2 = 3.867, df = 2, $p < 0.05$). There were significant associations between knowledge and perception: those who 'knew' about the genetic effects perceived lower risk than those who 'didn't know' (knowledge of genetic effects after the A-bombs: χ^2 = 38.536, df = 2, $p < 0.001$; knowledge of genetic effects after the Fukushima accident: χ^2 = 27.116, df = 2, $p < 0.001$). The results also indicate that 36.0% of those who responded 'I knew' about the genetic effects after the A-bombs perceived high genetic risk, with 48.2% for those who responded 'I've heard' and 65.7% for 'I didn't know.' There were no significant differences between genetic risk perception and other socio-demographic variables (sex, age, highest level of education, and occupation) or trusted sources of information ($p > 0.05$).

There was a significant difference in knowledge of the genetic effects of the A-bombs between Fukushima and Tokyo (χ^2 = 10.987, df = 2, p < 0.01; Figure 2). Those who ‘knew’ about the genetic effect of the A-bombs comprised 10.1% of the sample from Fukushima and 10.6% from Tokyo, while those who had heard about it comprised 32.0% of those from Fukushima and 21.9% from Tokyo. However, there was no significant difference in knowledge of the genetic effects of the Fukushima accident between the two geographical regions (χ^2 = 5.337, df = 2, p > 0.05).

Table 3. Associations between perceptions of genetic risk (The Lindell scale) and socio-demographic variables, knowledge, and trusted sources of information.

	Total n	(%)	(Very)Unlikely n	(%)	(very)likely n	(%)	χ^2	
Sex								
Men	427	(51.3)	188	(44.0)	239	(56.0)	1.384	
Women	405	(48.7)	162	(40.0)	243	(60.0)		
Age								
20s	169	(20.3)	79	(46.7)	90	(53.3)	5.220	
30s	214	(25.7)	79	(36.9)	135	(63.1)		
40s	236	(28.4)	95	(40.3)	141	(59.7)		
50s	213	(25.6)	97	(45.5)	116	(54.5)		
Highest level of education								
Junior or high school graduate	255	(30.6)	114	(44.7)	141	(55.3)	1.050	
University etc. graduate	577	(69.4)	236	(40.9)	341	(59.1)		
Occupation								
Employee etc.[a]	465	(55.9)	202	(43.4)	263	(56.6)	2.936	
Self-employed etc.[b]	48	(5.8)	24	(50.0)	24	(50.0)		
Other[c]	319	(38.3)	124	(35.4)	195	(40.5)		
Geographical Region								
Fukushima	416	(50.0)	189	(45.4)	227	(54.6)	3.867	*
Tokyo	416	(50.0)	161	(38.7)	255	(61.3)		
Knowledge of genetic risk after the A-bomb								
I knew	86	(10.3)	55	(64.0)	31	(36.0)	38.536	***
I've heard	224	(26.9)	116	(51.8)	108	(48.2)		
I didn't know	522	(62.7)	179	(34.3)	343	(65.7)		
Knowledge of genetic risk after the Fukushima Accident								
I knew	92	(11.1)	56	(60.9)	36	(39.1)	27.116	***
I've heard	181	(21.9)	92	(50.8)	89	(49.2)		
I didn't know	559	(67.2)	202	(36.1)	357	(63.9)		
Trusted source of information								
National press	323	(38.8)	124	(35.4)	199	(41.3)	2.929	
Local press	220	(26.4)	100	(28.6)	120	(24.9)	1.408	
Magazines	48	(5.8)	21	(6.0)	27	(5.6)	0.059	
Announcement by central governments	165	(19.8)	65	(18.6)	100	(20.7)	0.604	
Announcement by international organizations	176	(21.2)	70	(20.0)	106	(22.0)	0.482	

Public relations by local governments	140	(16.8)	64	(18.3)	76	(15.8)	0.919
Briefing sessions by the central & local governments	83	(10.0)	33	(9.4)	50	(10.4)	0.202
Doctors & stakeholders	209	(25.1)	90	(25.7)	119	(24.7)	0.113
Information heard from experts	201	(24.2)	86	(24.6)	115	(23.9)	0.056
Books written by experts	114	(13.7)	48	(13.7)	66	(13.7)	0.001
Information from families and acquaintances in the prefecture	62	(7.5)	26	(7.4)	36	(7.5)	0.001
Information from families and acquaintances outside the prefecture	23	(2.8)	10	(2.9)	13	(2.7)	0.019
Online information from experts	138	(16.6)	57	(16.3)	81	(16.8)	0.040
Online information from non-experts	45	(5.4)	13	(3.7)	32	(6.6)	3.390
Do not trust any of above	225	(27.0)	94	(26.9)	131	(27.2)	0.011

* p<0.05, *** p <0.001

[a] Company employee, civil servant, non-profit-organization employee, teacher, health professional, and other professionals.

[b] Agriculture, forestry, and fisheries workers and other self-employed workers.

[c] Part-time or casual worker, working on the side, housewife/husband, university student, technical college student, junior college student, preparatory school student, jobless, retired, etc.

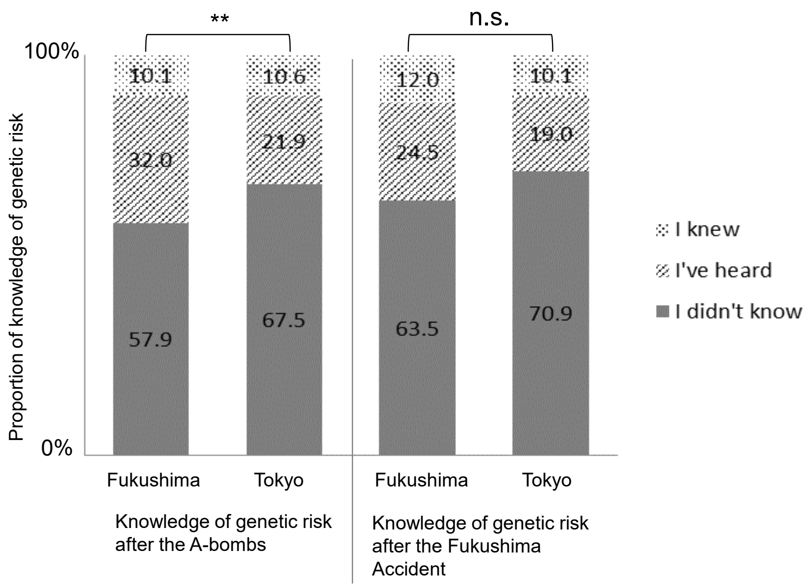

Figure 2. Regional differences in knowledge of the genetic effects of the A-bombs and Fukushima accident.
** p < 0.01, n.s. p > 0.05.

A binomial logistic regression analysis was then performed (Table 4). In Model 1, the odds ratio (OR) for high perceived risk was significantly lower than 1 for Fukushima (reference: Tokyo): 0.758, [95% confidence interval (CI): 0.575–0.999], p < 0.001. In Model 2, which included knowledge of the genetic effects of the A-bombs as an additional explanatory variable, the adjusted ORs for knowledge (reference: 'I didn't know' group) were as follows: 'I knew' group, 0.295, [95% CI: 0.183–0.475], p < 0.001; 'I've heard' group, 0.499, [95% CI: 0.362–0.688], p < 0.001. There was no significant association with geographical region (OR for Fukushima [reference: Tokyo]: 0.800, [95% CI: 0.603–1.063], p > 0.05).

Table 4. Results of a binomial logistic regression analysis for perceptions of genetic risk.

Variable	Perception of radiation risk, OR (95%CI)			
	Model 1		Model 2	
Geographical region (Reference: Tokyo)				
Fukushima	0.758	(0.575-0.999)	0.800	(0.603-1.063)
Knowledge of genetic risk after the A-bomb (Reference: I didn't know)				
I knew			0.295	(0.183-0.475)
I've heard			0.499	(0.362-0.688)

4. Discussion

To quantitatively understand the meaning of the responses to the Lindell scale by comparing them with other risks, the study used traffic accident mortality rates, which are relatively easy to understand and widely accepted, for a comparison of risks. There was a significant association between the perception of genetic risk and the perceived magnitude of that risk relative to traffic accident mortality rates, indicating the validity of the measure of the perception of genetic risk. However, it should be noted that 62.0% of the people who perceived genetic risk as (very) unlikely still overestimated that risk. Previous studies have reported that people generally overestimate low frequency hazards and underestimate high frequency hazards (i.e. primary bias) (Lichtenstein et al., 1978; Slovic et al., 1979). In addition, the risk of radiation has been found to be perceived as more dreaded and unknown than traffic accidents (Slovic, 1987), and our result is consistent with these findings. Overall, while the indicator of perception of genetic risks was validated, there was a tendency to make estimates of risk that were larger than the objective probability, and this was more pronounced for those who perceived a high risk.

The percentage of participants with a high perception of risk in Fukushima was 54.6%, which was higher than found in the FHMS. This could be attributed to the differences between the studies of the characteristics of the participants (in this study: Fukushima prefecture, 20 to 59 years old; in the FHMS: 13 municipalities in the evacuation zone, aged over 16 years) and the survey methods (online in this study; by mainly mail and repeated measurements in the FHMS). The perception of genetic risk in Fukushima was also lower than that in Tokyo, and Fukushima had a lower proportion of 'I didn't know' responses regarding knowledge of the genetic effects after the A-bombs and the Fukushima accident than did Tokyo.

It should be noted that, as of August 2018, the number of Fukushima residents evacuated to Tokyo was 3,864 (Fukushima prefecture, 2020), whereas the population of Tokyo was approximately 13,840,000 (Tokyo Metropolitan Government Bureau of General Affairs, 2018). Although some people might have evacuated from Fukushima to Tokyo due to their knowledge of radiation effects or the perceived genetic risk, this proportion among the participants in this study was considered negligible. The relationship between knowledge and geographic region is probably because living in Fukushima makes the topic more active and knowledge easier to acquire through risk communication and disaster-related information from local news reports, residents' briefing sessions, and community support.

The logistic regression analysis showed that geographical region was significantly associated with perception of genetic risk in the absence of knowledge but not in its presence, and that knowledge was significantly associated with lowered perception of genetic risk. Accordingly, the relationship between geographical region and risk perception was mediated by knowledge, but only about 10% of participants in both geographical regions answered ‘I knew’ regarding the lack of genetic effects of the A-bombs, indicating that such knowledge has not been extensively shared. In considering the impact of the Fukushima nuclear accident within the historical context of Japan, the genetic effects of radiation on the offspring of the A-bomb survivors are an important concern. Although there is substantial scientific evidence that radiation exposure by A-bombs does not affect the next generation (Neel et al., 1991), it was surprising that only about 10% of the respondents knew that there were no health effects on the offspring of the A-bomb survivors. In addition, since the participants were web survey registrants, they may have been more knowledgeable than the general public. The findings suggest that the importance of disseminating knowledge (e.g., the UNSCEAR report) regarding the scientific consensus on genetic effects could reduce the perceptions of genetic risk.

Nevertheless, approximately 40% of those who responded ‘I knew’ still had a high perception of risk, which indicates that perception is not governed by knowledge alone. The effectiveness and limitations of knowledge are consistent with previous findings regarding dual process theory in cognitive psychology (Kahneman, 2011). System 2 (slow, deliberative, and logical thinking), which can be promoted by knowledge, improves risk perception, while system 1 (fast, intuitive, and emotional thinking) is more likely to govern perception. While there is room for improving risk perception due to the drive of System 2, it is generally known that a schema (stereotype), such as images and stigma, comprising negative effects regarding radiation is fixed once it is formed and is hardly ever modified, even if new knowledge is acquired. In particular, for people outside Fukushima Prefecture who have had very little access to new information over time, such negative stereotypes may remain unchanged. A cognitive bias in information weighting and selective gathering, i.e., confirmation bias, may also support the maintenance of existing beliefs (Nickerson, 1998). Additionally, according to the prospect theory(Kahneman and Tversky, 1979), loss aversion looms large, and there is a psychological discontinuity between zero risk and extremely small probability. In other words, even if risk is known to be extremely small in probability, it will be perceived more strongly. A previous study regarding climate change has shown that personal experience is a predictor of risk perception and that risk perception and negative affect invoke reciprocal influences as a stable feedback system (van der Linden, 2014). It has been reported that the experience of the FDNPS accident associated the dread risk perception of radiation exposure and secondary physical health problems (Machida et al., 2020), and it is thus reasonable to assume that the risk perception formed from personal experience is maintained at a mutually high level with negative affect. The World Health Organization reported that an important goal of risk communication is to improve collective and individual decision-making, not through one-way communication from experts to the public, but through a more transparent and broader form of science and governance (Theakston, 2013). Furthermore, a previous study has shown that supporting general health anxiety rather than radiation risk perception leads to improved mental health (Kashiwazaki et al., 2020). Therefore, we emphasize the importance of supporting the emotional aspects regarding general health anxiety among the affected people through two-way risk communication, in addition to the efforts to share knowledge about countermeasures after a nuclear disaster.

This study had some limitations. First, there might be participation biases owing to the use of an online survey, as the panelists who are registered with the online research company may not reflect the whole population—for example, we confirmed that the proportion of junior or high school graduates was slightly lower than the population values. However, since incentives were given to the participants, the online survey had the advantage of obtaining answers, even if the participants had no interest in the subject matter, and a recent Japanese study reported that there was no significant difference in the perceptions of nuclear energy between an online survey and an interview survey (Kishikawa et al., 2018). Second, the age distribution of the participants in this study was limited to those under 60 years. Studies have indicated that older people generally have a higher perception of genetic risks than younger people (Y. Suzuki et al., 2015; Takebayashi et al., 2017), but participants over 60 years were excluded from the study due to problems of the potential representativeness of the online survey. Third, we focused particularly on the knowledge of genetic effects in this study, and other governing factors have yet to be investigated in depth. In particular, approximately 40% of the people with knowledge had a high perception of genetic risk, highlighting the importance of further investigations of other factors. Fourth, since it has been shown that the level of radiation anxiety in the Kanto region, including Tokyo, was comparable to that of other regions, except for Fukushima (Sekiya, 2016), other regions were excluded from the scope of the study. However, investigating the areas affected by the atomic bombs, such as Hiroshima and Nagasaki, may provide more information on the relationship between radiation risk perception and knowledge. Fifth, since our study was cross-sectional, the study design limits causal conclusions. Further research that includes interventions is needed to clarify the effects of knowledge on reducing the perception of risk. Additionally, the factors involved in risk perception should be examined from a wide range of approaches to risk communication, beyond cross-sectional and numerical statistics. Sixth, we used traffic mortality rates as a risk comparison to quantitatively understand the meaning of the responses to the Lindell scale. However, further information on the validity of the Lindell scale could be obtained by comparing it with various other risks of a different nature, such as risks associated with smoking and food additives. Seventh, we asked the participants whether or not they knew about the genetic effects of radiation noted by the UNSCEAR, but did not ask them about their other forms of knowledge about radiation. Further investigation of the relationship between the perception of radiation risk and diverse and objective knowledge about radiation is needed. Eighth, since this study was conducted almost seven years after the accident, it may not be applicable to the acute phase after an accident. Nevertheless, despite the limitations, this study provides a more advanced understanding of a potential solution for stigma and discrimination by clarifying that knowledge functions as a mediator for lowering the perception of genetic risk.

5. Conclusions

In this study, we confirmed the validity of the Lindell scale for measuring perceptions of genetic risk by comparing it with the mortality rate of traffic accidents in Japan. We confirmed that perception of genetic risk was lower in Fukushima than in Tokyo and that knowledge regarding genetic effects worked as a mediator to lower perceptions of genetic risk. However, approximately 40% of those who had such knowledge still showed high risk perceptions, highlighting that perception of genetic risk is not governed by knowledge alone. The delivery of knowledge regarding the genetic effects of radiation is both *necessary* and *important*, but it is not presently *sufficient*. Accordingly, interactive risk communication remains important for mitigating individual concerns, together with the sharing of knowledge.

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Conflict of interest

The authors state that there are no conflicts of interest.

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