



Perceptions of Residents in Relation to Smartphone Applications to Promote Understanding of Radiation Exposure after the Fukushima Accident: A Cross-Sectional Study within and outside Fukushima Prefecture

Yujiro Kuroda^{1,2}, Jun Goto³, Hiroko Yoshida⁴, Takeshi Takahashi⁵

¹Department of Prevention and Care Science, National Center for Geriatrics and Gerontology, Obu, Japan; ²Center for Integrated Science and Humanities, Fukushima Medical University, Fukushima, Japan; ³Institute for Research Promotion, Niigata University, Niigata, Japan; ⁴Radioisotope Research and Education Center, Graduate School of Pharmaceutical Sciences, Tohoku University, Sendai, Japan; ⁵Education Center for Engineering and Technology, Faculty of Engineering, Niigata University, Niigata, Japan

ABSTRACT

Original Research

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Corresponding author: Yujiro Kuroda

Department of Prevention and Care Science, National Center for Geriatrics and Gerontology, Obu 474-8511, Japan
E-mail: kuroda@ncgg.go.jp

<https://orcid.org/0000-0003-0587-5423>

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Background: We conducted a cross-sectional study of residents within and outside Fukushima Prefecture to clarify their perceptions of the need for smartphone applications (apps) for explaining exposure doses. The results will lead to more effective methods for identifying target groups for future app development by researchers and municipalities, which will promote residents' understanding of radiological situations.

Materials and Methods: In November 2019, 400 people in Fukushima Prefecture and 400 people outside were surveyed via a web-based questionnaire. In addition to basic characteristics, survey items included concerns about radiation levels and intention to use a smartphone app to keep track of exposure. The analysis was conducted by stratifying responses in each region and then cross-tabulating responses to concerns about radiation levels and intention to use an app by demographic variables. The intention to use an app was analyzed by binomial logistic regression analysis. Text-mining analyses were conducted in KH Coder software.

Results and Discussion: Outside Fukushima Prefecture, concerns about the medical exposure of women to radiation exceeded 30%. Within the prefecture, the medical exposure of women, purchasing food products, and consumption of own-grown food were the main concerns. Within the prefecture, having children under the age of 18, the experience of measurement, and having experience of evacuation were significantly related to the intention to use an app.

Conclusion: Regional and individual differences were evident. Since respondents differ, it is necessary to develop and promote app use in accordance with their needs and with phases of reconstruction. We expect that a suitable app will not only collect data but also connect local service providers and residents, while protecting personal information.

Keywords: Stakeholder Engagement, Risk Perception, Radiation Protection Culture

Introduction

Areas designated as evacuation zones in response to the accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) in March 2011 have been decontaminated with the aim of reducing exposure doses [1]. In areas where decontamination has been

completed and evacuation orders have been lifted, the prolonged evacuation has affected not only the physical aspects of the living infrastructure but also the psychosocial aspects of the affected residents, making it a major challenge to rebuild their lives as well as to restore the population [2–5]. The disaster-stricken municipalities have been working to establish a consultation system to help affected residents recover their livelihoods and to improve the attractiveness of the region for population recovery. They are promoting the migration of residents who have evacuated from their original areas but are hesitant to return to their homes, as well as those from outside their original areas [6, 7]. The recovery of the lives of the affected people is a challenge not only related to radiation in the affected areas but also their well-being in general, such as living infrastructure and social capital. Fukushima Prefectural Government, Ministry of the Environment (MOE), and related organizations have been engaged in various radiation risk communication activities because radiation doses and recognition of radiation risks in the affected areas are one of the factors that make residents hesitate to return or relocate.

Since the accident, radiation risk communication, namely, radiation dose measurement, radiation risk estimation, and tips for daily life in the contaminated area, have been carried out. For example, various organizations have conducted surveys of air radiation dose rates and exposure doses in the affected areas and published the data [7–10]. In Fukushima Prefecture, many monitoring sites have been set up, and the results are publicly available on the Nuclear Regulation Agency (NRA) Radiation Monitoring Information website [11]. Residents of the disaster-stricken areas have many opportunities to obtain information on air dose rates, exposure doses, and radiation levels [12]. However, it is difficult to understand the concept of radiation dose rates even for the residents of the affected areas who have been routinely exposed to scientific information after the accident [13]. Previous studies have shown that (1) radiation itself is difficult for non-experts to understand, (2) man-made risk is perceived as a greater risk, and (3) distrust in radiation experts and the scientific information they provide, developed early after the accident. In addition, to overcome these difficulties, some projects have tried to communicate with disaster-affected residents based on the data, rather than just disclosing the radiation dose [14]. In the Miyakoji district of Tamura City and Suetsugi district of Iwaki City, the relationship between external exposure dose and behavior patterns was clarified using the D-Shuttle

personal dosimeter (Chiyoda Technol Corp., Tokyo, Japan) to facilitate communication between residents and experts [15, 16]. After the lifting of the evacuation order, Iitate village and other local governments in the area also implemented such measures [5]. Safecast, a citizen-science project, provides radiation data around the world. Following the Fukushima accident, citizen-scientists constructed a radiation sensor network consisting of fixed and mobile sensors deployed throughout Japan, including around the restricted area, and effectively utilized technology to collect and visualize radiation data in the area in real-time [17]. To obtain lessons from the Fukushima and Chernobyl disasters, the SHAMISEN project (<https://radiation.isglobal.org/shamisen>), implemented in the European Union, conducted case studies that incorporated not only the direct effects of radiation but also the social and ethical implications of the accident indirectly. One of the recommendations pointed out the need for residents to participate in radiation dosimetry after a nuclear disaster [14, 18]. The report also states that residents' voluntary use of technology promotes communication with support staff and improves their self-control [19, 20]. The World Health Organization (WHO) e-Health guidelines recommend timely sharing of health data to facilitate communication with service providers [21]. Some of the aforementioned good practices have not been widely available to the public due to their technical aspects. Therefore, the development of smartphone applications (apps) is a possible means to promote the use of technology and communication. However, it is necessary first to examine residents' perceptions toward radiation apps. To the best of the author's knowledge, no such survey has been conducted.

Therefore, an exploratory study was conducted to clarify the perception about the necessity of a smartphone app for monitoring radiation doses through a cross-sectional survey of residents in and outside Fukushima Prefecture. Furthermore, by exploring residents' concerns about their radiation, we examined cases where the app could be used effectively. The results will lead to more effective methods for identifying target groups for future app development by researchers and municipalities, which will promote residents' understanding of radiological situations.

Materials and Methods

This research group, a collaboration between basic researchers studying radiation and social science, was adopted by the

Japanese MOE. The main objective of the research team was to develop an app to easily estimate individual exposure doses and make it available to the general public to promote understanding of radiation and reduce excessive anxiety in the wake of the Fukushima disaster. We envisioned the development of an app that would provide an easy-to-understand graph of an individual's annual exposure dose with a comparison to the Japanese average by inputting information such as residential address, workplace, school address, time spent on each place, and radioactivity contained in food. Prior to the development of the app, a cross-sectional survey was conducted to ascertain the current state of radiation concerns among citizens in and outside Fukushima Prefecture and to examine their perceptions on the app. As the need for apps would differ between Fukushima Prefecture, which was affected by the FDNPP accident, and other prefectures, the survey targeted residents within Fukushima Prefecture and outside it, 400 in each region. The participants were selected to have equal gender and age ratios. The survey was conducted on the Internet in November 2019.

Radiation protection experts on the research team, social psychologists, and ethicists devised the survey items. There were four parts:

- (1) Basic characteristics: place of residence, gender, age, presence of children under high school age, residence within 20 km of the NPP, and experience of evacuation.
- (2) Concerns about radiation level: In response to the question, "When does radiation dose matter to you?" the respondents answered multiple questions concerning medical exposure to radiation, purchasing agricultural and livestock products (purchasing foods), eating vegetables grown and fish caught by themselves (eating own-grown foods), living near or visiting a nuclear power plant (living close to NPP), visiting areas affected by the accident (visiting affected areas), living in areas affected by the accident (living close to FDNPP), and natural exposure.
- (3) Intention to use the app: In response to the question, "Would you like to use an app to estimate individual exposure dose?" the respondents answered on a five-item scale of "very much, a little, can't say, not much, not at all."
- (4) Free description: Why participants do or don't want to use an app. Since a radiation app has not previously been devised, the items in the questionnaire were selected with the participation of social scientists using the advice of the local government. The ethics committee of Niigata University approved this study (No. 2019-0250).

First, we stratified responses within and outside the prefecture, and then cross-tabulated responses to concerns about radiation level by gender. Second, we compared the intention to use an app and associated characteristics (gender, age, family structure, evacuation experience, living near the NPP, and measurement experience) in both regions. Categorical variables were compared by chi-squared test. Third, the relationship between the types of concerns and the intention to use an app was compared between regions. Odds ratios (ORs) and 95% confidence intervals were estimated by binary logistic regression analysis, with the intention to use an app as the outcome and types of concern as explanatory variables. Background factors were used as adjustment factors to determine adjusted odds ratios (AORs). Finally, text-mining analyses were conducted in KH Coder software (version 3; <https://kncoder.net/en/>), to explore reasons using qualitative data. Frequently used words were listed, and a subgraph analysis of a co-occurrence network was conducted to classify these words into major topics [22]. Jaccard coefficients were calculated to determine the edge strength in the co-occurrence network. Those with top-60 strength were drawn in the diagram, and closely associated words were color coded. To examine the characteristics of the free description in each region and the intention to use an app (positive and negative group), we analyzed four groups; words common to all four groups are shown in dark green, to three in light green, to two in yellow, and to one in orange. Of the five answers to questions about their intention to use the app, "very much" and "little" are defined as the positive group, and the rest as the negative group.

Results and Discussion

Of the respondents outside Fukushima Prefecture, four had evacuated. Since it is possible that some respondents had evacuated from Fukushima Prefecture, which means they may have originally been residents of Fukushima Prefecture, they were excluded from the analyses. Although the needs of such evacuees are also valid, we did not acquire enough data to analyze them. The total number of subjects analyzed was 400 within Fukushima and 396 outside Fukushima. As for gender, women accounted for 50% within and outside Fukushima.

Table 1 shows the comparison results of the intention to use the app with background factors in Fukushima Prefecture and other prefectures. Within Fukushima had 128 posi-

Table 1. Relationship between the Intention to Use an App and Related Factors by Region

Variable	Intention to use					
	Within Fukushima (n=400)			Outside Fukushima (n=396)		
	Use	Not use	P-value	Use	Not use	P-value
Gender			0.592			0.383
Male	67 (33.5)	133 (66.5)		56 (29.0)	142 (71.0)	
Female	61 (30.5)	139 (69.5)		65 (33.0)	133 (67.0)	
Age group (yr)			0.124			0.439
20–39	60 (37.5)	100 (62.5)		54 (34.2)	104 (65.0)	
40–59	43 (26.9)	117 (73.1)		44 (27.8)	114 (72.2)	
≥60	25 (31.3)	55 (68.8)		23 (28.7)	57 (71.3)	
Family structure			0.003*			0.218
With children	41 (45.6)	49 (54.4)		93 (29.2)	226 (70.8)	
Without children	87 (28.1)	223 (71.9)		28 (36.4)	49 (63.8)	
Experience of evacuation			0.012*			-
Experience	33 (45.2)	40 (54.8)		-	-	
No experience	95 (29.1)	232 (70.9)		121 (30.6)	275 (69.4)	
20 km from NPP			0.574			0.643
Within	6 (40.0)	9 (60.0)		2 (40.0)	3 (50.0)	
Outside	122 (31.7)	263 (68.3)		119 (30.4)	272 (69.6)	
Experience of measurement			0.03*			0.004*
Experience	52 (39.4)	80 (60.6)		7 (77.8)	2 (22.2)	
No experience	76 (28.4)	192 (71.6)		114 (29.5)	273 (70.5)	

Values are presented as number (%).

* $P < 0.05$, χ^2 test used for categorical variables.

tive responses (32%) and outside Fukushima 121 positive responses (31%) among men and women. Within Fukushima, having children under the age of 18 in the family structure, the experience of measurement, and having experience of evacuation were significantly related to the intention to use an app. Outside Fukushima, only the experience of measurement was related. Univariate analysis showed that those who had children and the experience of evacuation, were more likely to have an intention to use the app among the participants in Fukushima Prefecture. Previous studies have reported that these factors are also related to high radiation risk perception [23]. Furthermore, the experience of measurement was considered to be a promoting factor, both inside and outside Fukushima Prefecture. Introducing the app to individuals with high-risk perceptions and who have been engaged in measurement activities after the accident in Fukushima was thought to promote the usage of the app.

Next, when the types of concerns were compared with the intention to use the app, significant associations were found for all items, except a concern about living near the FDNPP within the prefecture (Table 2), which may have indicated that there is no other NPP in Fukushima Prefecture besides the crippled one and the suspended Fukushima Daini. Out-

side of Fukushima, significant associations were shown for items other than those living near FDNPP (Table 2), which may be unrealistic for individuals outside Fukushima, even if they might visit the affected areas. Among the items with high ORs, within Fukushima Prefecture, people with concerns about purchasing foods, eating own-grown foods, and visiting affected areas were more than three times as likely to want to use an app as those without such concerns (Table 2). Previous research has shown that knowing the radiological context can help alleviate concerns, and it is expected that using an app will also be relevant [14]. However, verification of its effectiveness will be necessary after the app is developed. Outside Fukushima Prefecture, people with concerns about purchasing foods, consuming own-grown foods, and having natural exposure were more than three times as likely to want to use an app (Table 2). Regarding the items corresponding to the concern of purchasing foods, the AOR was higher outside the prefecture than that within Fukushima Prefecture. This may indicate the fact that the radioactivity in foods produced within Fukushima Prefecture being measured is not sufficiently known outside the prefecture, and those individuals may wish to confirm this using the app. Regarding concerns about natural radiation, the higher AOR

Table 2. Relationship between Intention to Use an App and Related Factors by Region: Multivariate Analysis

Type of concern	Within Fukushima (univariate analysis)				Outside Fukushima (multivariate analysis)			
	n (%)	Intention to use (applicable)	OR (95% CI) ^{a)}	AOR (95% CI) ^{a)}	n (%)	Intention to use (applicable)	OR (95% CI) ^{a)}	AOR (95% CI) ^{a)}
Medical exposure								
Present	105 (26.3)	45 (42.9)	1.92 (1.21–3.04)	2.05 (1.26–3.32)	129 (32.3)	58 (45.0)	2.56 (1.63–4.00)	2.84 (1.76–4.57)
Absent	295 (73.8)	83 (28.1)	1.00	1.00	271 (67.8)	66 (24.4)	1.00	1.00
Purchasing foods								
Present	115 (28.7)	62 (53.9)	3.88 (2.45–6.13)	3.93 (2.43–6.34)	101 (25.3)	58 (57.4)	4.80 (2.96–7.78)	5.02 (3.04–8.29)
Absent	285 (71.3)	66 (23.2)	1.00	1.00	299 (74.8)	66 (22.1)	1.00	1.00
Eating own-grown foods								
Present	138 (34.5)	68 (49.3)	3.27 (2.10–5.08)	3.31 (2.07–5.28)	72 (18.0)	38 (52.8)	3.23 (1.90–5.49)	3.29 (1.91–5.68)
Absent	262 (65.5)	60 (22.9)	1.00	1.00	328 (82.0)	86 (26.2)	1.00	1.00
Living close to NPP								
Present	84 (21.0)	35 (41.7)	1.71 (1.04–2.81)	1.53 (0.91–2.57)	83 (20.8)	38 (45.8)	2.17 (1.31–3.58)	2.07 (1.23–3.47)
Absent	316 (79.0)	93 (29.4)	1.00	1.00	317 (79.3)	86 (27.1)	1.00	1.00
Visiting affected areas								
Present	87 (21.8)	47 (54.0)	3.37 (2.06–5.50)	3.13 (1.87–5.24)	80 (20.0)	39 (48.8)	2.61 (1.57–4.34)	2.65 (1.55–4.52)
Absent	313 (78.3)	81 (25.9)	1.00	1.00	320 (80.0)	85 (26.6)	1.00	1.00
Living close to FDNPP								
Present	75 (18.8)	38 (50.7)	2.68 (1.60–4.48)	2.60 (1.51–4.47)	53 (13.3)	22 (41.5)	1.72 (0.94–3.13)	1.60 (0.86–3.00)
Absent	325 (81.3)	90 (27.7)	1.00	1.00	347 (86.8)	102 (29.4)	1.00	1.00
Natural exposure								
Present	59 (14.8)	28 (47.5)	2.18 (1.24–3.82)	1.88 (1.04–3.40)	57 (14.2)	33 (57.9)	3.92 (2.19–6.99)	3.61 (1.99–6.56)
Absent	341 (85.3)	100 (29.3)	1.00	1.00	343 (85.8)	91 (26.5)	1.00	1.00

OR, odds ratio; CI, confidence interval; AOR, adjusted OR; NPP, nuclear power plant; FDNPP, Fukushima Daiichi Nuclear Power Plant.

^{a)}Binomial logistic regression analysis used the intention to use an app as the outcome and types of concern as the explanatory variables.

outside Fukushima Prefecture than that within the prefecture may be because monitoring posts are installed at various locations in Fukushima Prefecture, and information on radiation doses is obtained through daily news broadcasts, while there is no such information available outside the prefecture. Finally, the concern of medical exposure outside the prefecture was examined. Outside the prefecture, medical exposure accounted for the highest concern, for which women were significantly concerned. Concerns about medical exposure followed the same trend and supported the results of previous studies [23, 24]. Whether or not the use of the app would dispel the high concern about medical radiation exposure has not been fully investigated, and future research results are desired.

A sub-graph analysis of the relationships between words in the free description generated 10 categories: exposure dose in daily life, current situation in Fukushima, ease of checking by app, visiting affected areas and NPP, children, smartphone, ease of use of the app, understanding radiation levels, concern, and no interest (Fig. 1). The following are some of the comments that the respondents made regarding

using the app: “It helps me understand how serious/dangerous the situation in Fukushima is compared to where I currently reside,” “I do not want to increase false knowledge about radiation any further,” “I do not want to find out later that I was exposed to radiation,” and “It helps me know, in a reasonable manner, the amount of radiation I have been exposed to.” However, some respondents were not interested in the apps because they stated “I used to be curious about radiation doses, but now I do not care as much as I used to.” The reason that the apps were often associated with the term “unnecessary” is thought to be the lapse of time between the accident and the survey; however, those who were interested indicated that they intended to use the apps as tools to compare radiation doses between regions, and to measure the radiation doses by themselves, to help further their understanding of radiological situations. Within Fukushima Prefecture, the positive group was consistent in wanting to know about radiation accidents as indicated by the usage of words such as accident, radiation, know, and self. However, the negative group felt no need as indicated by the usage of words such as particularly, smartphone, apps, and need (as-

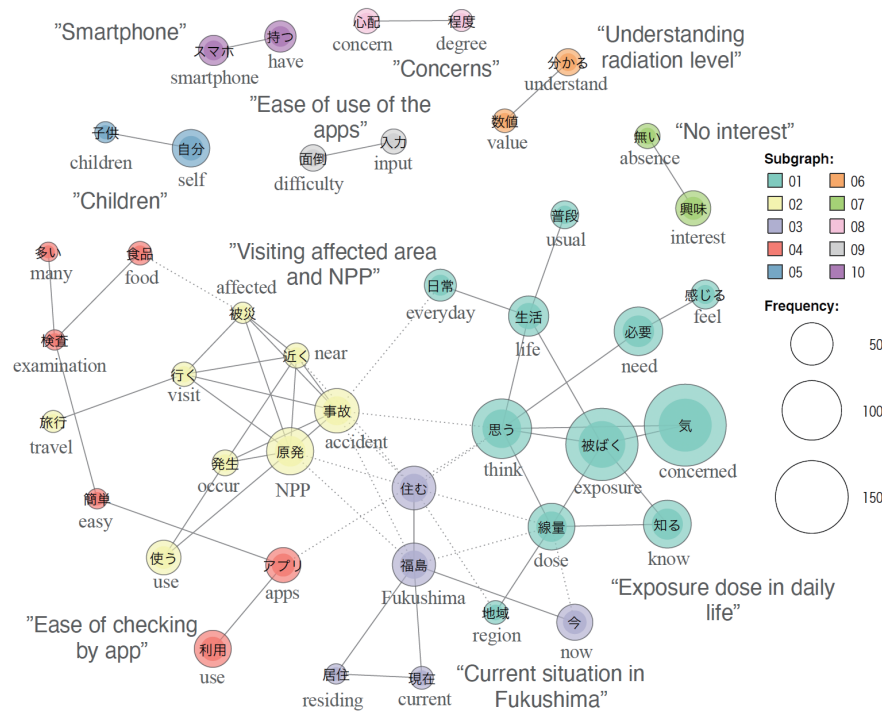


Fig. 1. Sub-graph analysis of a co-occurrence network among participants with regard to apps. Each colour indicates a cluster of words (topic) used frequently in sentences. The following 10 topics were extracted: exposure dose in daily life, current situation in Fukushima, ease of checking by app, visiting affected areas and nuclear power plant (NPP), children, smartphone, ease of use of app, understanding radiation levels, concern, and no interest.

sociated with unnecessary) (Fig. 2). In the negative group, respondents from Fukushima Prefecture extracted the terms “troublesome” and “have” and felt that “using the app is troublesome.” However, respondents from outside of Fukushima Prefecture extracted the terms “use,” “everyday,” and “feel” and felt that there is no need to use the app. Within the positive group, on the other hand, respondents in Fukushima Prefecture wanted to know their own radiation dose, and felt a need for a tool to easily show the effects of radiation when visiting damaged areas and areas around other NPPs. The above analysis reveals regional differences in desired app usage: Those outside the prefecture would use an app if they visited an affected area, but not in their daily life. This is because the terms in this group are associated with “travel” and “visit,” while “usual” is associated with “un-usual.” Those within the prefecture, the terms “accident,” “radiation,” “know,” and “self” were common to those outside the prefecture, and only “residing” was the only term that appeared independently within the prefecture. Residents want to know the radiation levels associated with the accident by themselves using the app, and in addition, they want to know about their own living environment. In many cases, the negative group did not

feel the need for the app, and the positive group showed different purposes of use within and outside the prefecture. Considering this, at the stage of developing and disseminating the app, it is necessary to explain not only what an app is capable of, but also the specific benefits of having the app, according to the target group.

The results of concerns about radiation levels by region are shown in Fig. 3. Out of the seven concerns, based on the 75 percentile (an item with more than 25% responses), concerns about medical exposure (32.3%) and purchasing foods (25.3%) were applicable outside Fukushima Prefecture. In Fukushima Prefecture, concerns about medical exposure (26.3%), purchasing foods (28.7%), and eating own-grown foods (34.5%) were considered to be the main concerns. In the comparison of gender differences, the percentage of women who responded that they were concerned about medical exposure outside Fukushima Prefecture, and that they were concerned about medical exposure and eating own-grown foods in Fukushima Prefecture were significantly higher than that of men. In addition to the results of this survey, our previous study also showed that women in Fukushima Prefecture tend to avoid products from Fukushima Pre-

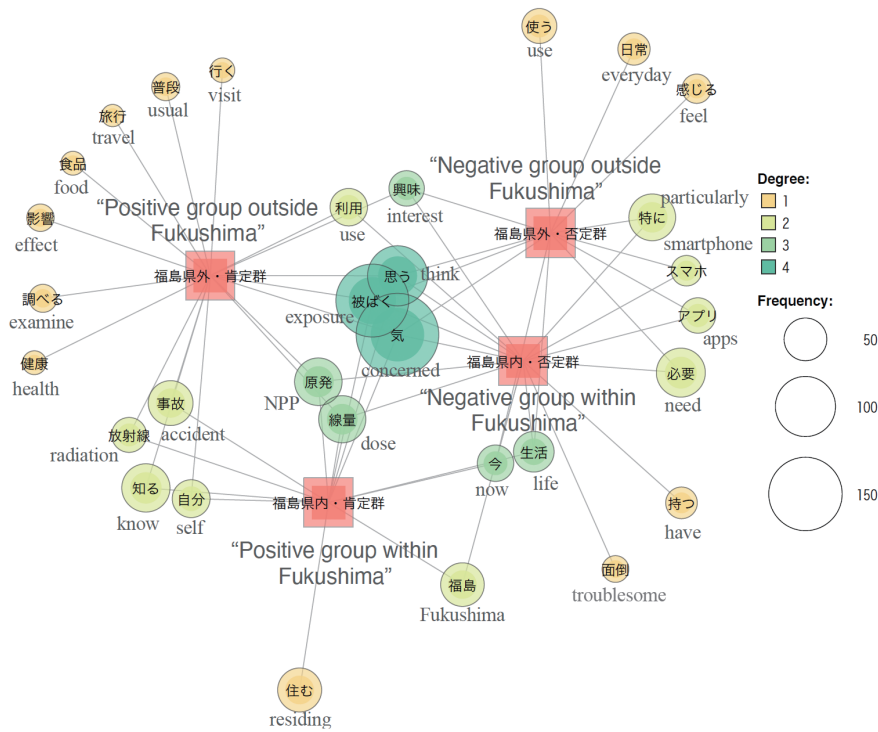


Fig. 2. Sub-graph analysis of intentions to use the app: free descriptions within and outside Fukushima Prefecture and the positive and negative groups. Free description in each region (within Fukushima and outside Fukushima) and intention to use an app (positive and negative group) were extracted. Words common to all four groups are shown in dark green, to three groups in light green, to two groups in yellow, and to one group in orange. NPP, nuclear power plant. App, application.



Fig. 3. Concerns about radiation levels within and outside Fukushima prefecture. χ^2 test used for categorical variables. $P < 0.05$ was considered statistically significant. NPP, nuclear power plant.

fecture after the disaster. In addition, a cohort study of women of childbearing age throughout Japan showed that the anxiety of women in Fukushima after the accident was significantly higher than that in the rest of Japan [25]. These results suggest that women living in Fukushima could be a major target for the app, which should incorporate food purchases and own-grown foods [26]. Although the concerns of Fukushima Residents have changed over time and varied by region, i.e., Hamadori (including the evacuation zone), Nakadori, and Aizu (the mountainous areas furthest from the NPP), they may have strong concerns about eating local food for the following reasons; local residents are already generally aware that certain foods (wild mushrooms, wild boar, etc.) are highly contaminated, and while most residents' risk perceptions are intermediate, they are also divided by the sense of safety and avoidance [26–28]. Those who do not care about the contamination considered eating locally caught food as a part of their culture and reported that they would not stop eating it even if they know that it is contaminated. Additionally, although they initially measured the contamination, over time they stopped measuring it since it was too much of a hassle to take it to a measurement station, and began eating it without worrying about the contamination. However, those who are concerned about the contamination do not agree with this behavior—resulting in sophistry among families and communities. Furthermore, the latter may have a general distrust of food, and although they know that products from Fukushima Prefecture are inspected, they are worried that contaminated products may be mixed in with the other products. In addition, internal exposure also has a higher risk perception than external exposure [29], and there may be a bias in risk perception due to the routine behavior of eating food. In a recently published study by Della Monaca et al. [30] the main situations that were reported as very high risk were accidents at nuclear facilities (33.0%, very high), terrorist attacks with radiation sources (30.9%, very high), air pollution, chemical waste, and accidents at chemical facilities. The lowest risk was medical exposure, including medical X-rays, computed tomography (CT) scans, and positron emission tomography (PET) scans. Since the subjects of the previous study were a group of experts, we believe that there is a large difference in the perception of medical exposure between the group with expertise and the general group, and this difference is not recognized between the regions within and outside Fukushima Prefecture.

Since this study used a web survey, it is possible that the

respondents are limited to those with high technology literacy. In addition, as the number of participants in the evacuation areas in Fukushima Prefecture is limited, it is possible that their needs are not fully understood. Further, the difference in sensitivity to radiation between the regions within and outside Fukushima has been identified by previous studies as a result of multiple factors, but one of the most important factors is “distrust” of radiation information and the experts and government that provide the information. It is possible that this indirectly influences the intention to use the app, but since these variables were not assessed as mediating variables in this study, a full discussion cannot be made. In the future, it is recommended to survey a wider range of subjects by mail, to interview residents in evacuation areas, and to use mediator variables including distrust on information when developing apps.

Conclusion

In our analysis of residents' concerns and the need for an app, we found regional and individual differences. Participants who had children and had experienced the disaster had such needs, and their needs tended to increase when they had concerns about daily life, such as purchasing foods or eating own-grown foods. Since residents differ, it is necessary to develop and promote app use in accordance with their needs. Early detection of residents' concerns and addressing them in an app could allay them. Using apps to visualize measurements is useful, but indicators such as “doses are low compared to other areas” (and therefore safe) may have a limited role 10 years after the accident. In Fukushima after the accident, pioneering approaches were implemented for experts to measure individual exposure doses and internal exposure doses and to visualize the results for discussion with the community, fostering a sense of security in continuing to live in the community [16, 19]. The WHO e-Health guidelines recommend that health data be shared in a timely manner to facilitate communication with service providers [31, 32]. The app could also be used to create virtual communities and organize information according to the different groups identified, which could help develop radiation protection culture. Therefore, the developed app must not only collect data, but also connect local service providers and residents, while protecting personal information.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Author Contribution

Conceptualization: Kuroda Y. Data curation: J Goto, Takahashi T. Formal analysis: Kuroda Y. Funding acquisition: Takahashi T. Methodology: Kuroda Y. Writing - original draft: Kuroda Y. Writing - review & editing: Kuroda Y, Goto J, Yoshida H, Takahashi T. Investigation: Kuroda Y. Supervision: Yoshida H. Validation: Kuroda Y.

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