

# Current situation survey for establishing personally acceptable radiation dose limits for nuclear disaster responders

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## ABSTRACT

When responding to disasters, emergency preparedness is essential to ensure that disaster activities are performed smoothly, safely and efficiently. Investigations on the Fukushima accident revealed that lack of preparedness, poor communication and unsuitable emergency measures contributed to an inadequate emergency response to the nuclear disaster. In this study, we conducted a questionnaire survey on the establishment of a personal radiation exposure dose among Disaster Medical Assistance Team (DMAT) members in Japan who might be involved in the initial response to a nuclear disaster. Establishing personal exposure doses for personnel can encourage emergency preparedness and inform decisions on appropriate role assignments during nuclear response activities. Valid responses were obtained from 178 participants, and the response distribution was as follows: 'Already have own acceptable dose standard,' 16 (9%); 'Follow own institution's standard (and know its value),' 30 (17%); 'Follow own institution's standard (but do not know its value),' 59 (33%); 'Haven't decided,' 63 (35%) and 'Don't understand question meaning,' 10 (6%). We also assessed intention to engage in nuclear disaster activities among respondents via engagement intent scores (EIS) and found that participants who had established personal exposure standards had significantly higher EIS scores than those who had not decided or who did not understand the question. Thus, educating potential nuclear disaster responders on personal exposure doses may contribute to a higher intention to engage in emergency responses and improve preparedness and response efficiency.

**Keywords:** nuclear disaster; acceptable exposure dose; DMAT; radiation; emergency preparedness

## INTRODUCTION

In recent years, the number of reported natural disasters has increased substantially worldwide [1]. In disasters or emergency situations, rapid and smooth responses are required to prevent loss of life and environmental damage. When a major earthquake triggered the Fukushima Daiichi nuclear power plant (FDNPP) accident, several factors, including lack of preparedness, poor communication and unsuitable emergency measures, contributed to an inadequate emergency response [2]. Therefore, when providing medical treatment in areas where hazards exist, advanced measures to facilitate disaster response activities are essential.

The intention to engage in nuclear disaster responses is lower than the intention to engage in natural disaster responses among first responders in medical professions or firefighters [3–6]. Surveys have revealed that even those willing to respond to natural hazards avoid involvement in nuclear disasters due to anxiety and lack of knowledge on nuclear hazards [7, 8]. The low intention to engage in nuclear disaster response is one of the main obstacles to efficient disaster activities, along with factors such as anxiety, lack of knowledge, low frequency of nuclear disasters, special equipment requirements and unpreparedness of disaster responders. Among them, the current status of disaster responder preparedness for a

nuclear disaster and necessary measures to achieve preparedness are unclear.

In Japan, the Great Hanshin-Awaji Earthquake of 1995 led to the establishment of a disaster medical system and a designated Disaster Medical Assistance Team (DMAT) to respond to various disasters. The DMAT is defined in the Basic Disaster Management Plan of Japan's Disaster Countermeasures Basic Act [9, 10]. DMAT members are specialists in disaster responses and must accept certain health risks, such as radiation exposure during a nuclear disaster. However, DMAT was not originally designed to be dispatched for nuclear disasters. In contrast, a majority of the nuclear disaster medical dispatch team members are DMAT members. Therefore, it is necessary to investigate the preparedness of DMAT personnel to perform acute phase activities in the event of a nuclear disaster, facilitating efficient nuclear disaster responses.

The International Commission on Radiological Protection (ICRP) proposed an acceptable exposure value of 100 mSv in 5 years for workers, which is used as a reference for engaging in radiation-related work in a clinical setting [11]. Although this value is a legal limitation, it does not provide a legal basis for forcing workers to continue providing clinical treatment until the specified value has been reached. Workers are allowed to cease working at their will before reaching this standard. Therefore, DMAT personnel should set a personal exposure tolerance and be fully informed of the potential risks before engaging in nuclear disaster response activities. In addition, from the standpoint of the commander, knowing in advance the acceptable exposure dose for each member of the team can inform decisions on appropriate role assignments. For example, personnel with higher acceptable doses may be assigned to frontline roles, whereas those with lower acceptable doses may be assigned to work behind the scenes.

In this study, we surveyed DMAT personnel to determine whether they had established a personal acceptable radiation exposure dose for a nuclear disaster activity. Further, we provided radiation education recommendations for people who may engage in nuclear disaster response activities.

## MATERIALS AND METHODS

An anonymous web questionnaire survey was conducted from October 2020 to November 2020. The questionnaire URL was distributed to the DMAT personnel mailing list in two different areas; one was a nuclear disaster-affected area, and the other was a non-affected area. The term 'nuclear disaster-affected area (Group A)' refers to Fukushima prefecture, which experienced a nuclear power plant accident, while the term 'non-affected area (Group N)' refers to a prefecture more than 500 km away from Fukushima prefecture that was not directly affected by the FDNPP accident and has a nuclear emergency core hospital. Ninety-three personnel from Group A and 111 personnel from Group N responded to the questionnaire. Incomplete questionnaire responses were excluded, resulting in the inclusion of 79 (85%) and 99 (89%) responses from Groups A and N, respectively, in the final analysis. The participants were divided into four groups according to age and area: younger Group A ( $\leq 39$  years old; nuclear disaster-affected area), older Group A ( $\geq 40$  years old; nuclear disaster-affected area), younger Group N ( $\leq 39$  years old; non-affected area) and older Group N ( $\geq 40$  years old; non-affected

area). The reference age of 39 years was the mean age of DMAT members (38.8 years) [12]. The demographic characteristics of study participants are shown in Table 1. The questionnaire asked, 'Have you established your own acceptable standard of radiation exposure dose for engaging in nuclear disaster activities?' with five response choices, as shown in Table 2. The response distributions were compared between the four groups (younger and older, Group A and N). The background characteristics and questionnaire responses were compared between the four groups using the chi-squared test and Fisher's exact test using R 4.0.3 software (R Foundation for Statistical Computing; Vienna, Austria). Additionally, we included the question, 'Will you actively engage in response activities during a nuclear disaster?' to validate the participant's intention to engage in nuclear disaster response activities. The participants were required to respond to the above question using a scale of 0%–100%; this value is referred to as the engagement intent score (EIS), which was originally coined by the authors [3, 6]. The relationship between the participants' responses to the acceptable exposure dose question and the EIS was analyzed using the Tukey–Kramer test. All statistical analyses were performed using SPSS statistics 27 (IBM Corp., Chicago, IL, USA), and the significance level was set at 0.05. The present study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Fukushima Medical University (approval number: 2020–130).

## RESULTS AND DISCUSSION

This study was conducted for the final purpose of facilitating smooth and efficient responses to nuclear disasters. Lack of awareness and knowledge have been identified as factors that hindered an organized and timely response to the Fukushima nuclear accident [2]. In this study, awareness of an acceptable radiation exposure dose was investigated as a surrogate marker to assess the status of preparedness.

The characteristics of participants are shown in Table 1. No significant differences in background factors among the four groups were detected, with the exception of occupation and experience in natural disaster activities ( $P = 0.048$  and  $0.012$ , respectively). When asked whether they had established a personal acceptable standard of radiation exposure, 89 (50.1%) respondents indicated that they would follow the institution's standard, 63 (35.4%) indicated that they had not decided and only 16 (9.0%) had already established an acceptable radiation dose for themselves (Table 2). No significant differences in the answer distributions were detected among the four groups ( $P = 0.196$ ).

When participating in a high-risk disaster response activity, there is a compromise between engaging in the emergency response and reducing one's own health risk. Thus, it is ideal for disaster responders to set acceptable standard values for themselves in advance. This report revealed that most DMAT personnel had not established a personal acceptable radiation dose, and among the 89 who indicated that they would follow the institution's standard, 59 (66.3%) did not know that value. These results suggest there is a lack of awareness and knowledge surrounding personally acceptable radiation doses, indicating education on this topic could improve preparedness for nuclear disaster response situations.

The average EIS for each acceptable personal exposure dose level was as follows: 'Already have own acceptable dose standard,' 82.3;

**Table 1. Characteristics of participants**

	Younger Group A (n = 28)	Younger Group N (n = 56)	Older Group A (n = 51)	Older Group N (n = 43)	P value
Sex, n (%)					
Female	6 (21.4)	17 (30.4)	18 (35.3)	9 (20.9)	0.368
Male	22 (78.6)	39 (69.6)	33 (64.7)	34 (79.1)	
Age (years), n (%)					
20–29	6 (21.4)	8 (14.3)	—	—	0.408 <sup>a</sup>
30–39	22 (78.6)	48 (85.7)	—	—	
40–49	—	—	33 (64.7)	34 (79.1)	0.125 <sup>b</sup>
Over 50	—	—	18 (35.3)	9 (20.9)	
Occupation, n (%)					
Physician	3 (10.7)	8 (14.3)	17 (33.3)	13 (30.2)	0.048
Nurse	7 (25.0)	27 (48.2)	20 (39.3)	15 (34.9)	
Administrative staff	7 (25.0)	9 (16.1)	7 (13.7)	7 (16.3)	
Others	11 (39.3)	12 (21.4)	7 (13.7)	8 (18.6)	
Family (dependents), n (%)					
Without	6 (21.4)	16 (28.6)	11 (21.6)	10 (23.3)	0.822
With	22 (78.6)	40 (71.4)	40 (78.4)	33 (76.7)	
Experience in engaging in natural disaster activities, n (%)					
No	12 (42.9)	24 (42.9)	9 (17.6)	10 (23.3)	0.012
Yes	16 (57.1)	32 (57.1)	42 (82.4)	33 (76.7)	
Experience in engaging in CBRNE disaster activities, n (%)					
No	27 (96.4)	53 (94.6)	45 (88.2)	39 (90.7)	0.495
Yes	1 (3.6)	3 (5.4)	6 (11.8)	4 (9.3)	

CBRNE, chemical, biological, radiological, nuclear and explosive; younger Group A, ≤39 years old in nuclear disaster-affected area; younger Group N, ≤39 years old in non-affected area; older Group A, ≥40 years old in nuclear disaster-affected area; older Group N, ≥40 years old in non-affected area.

<sup>a</sup>Comparison between younger Group A and younger Group N. <sup>b</sup>Comparison between older Group A and older Group N.

**Table 2. Responses to the establishment of personally acceptable radiation exposure doses**

	Total (n = 178)	Younger Group A (n = 28)	Younger Group N (n = 56)	Older Group A (n = 51)	Older Group N (n = 43)
Already have own acceptable dose standard, n (%)	16 (9.0)	4 (14.3)	2 (3.6)	5 (9.8)	5 (11.6)
Follow own institution's standard (and know its value), n (%)	30 (16.9)	6 (21.4)	7 (12.5)	12 (23.5)	5 (11.6)
Follow own institution's standard (but do not know its value), n (%)	59 (33.2)	5 (17.9)	20 (35.7)	18 (35.3)	16 (37.2)
Have not decided, n (%)	63 (35.4)	12 (42.8)	20 (35.7)	15 (29.4)	16 (37.2)
Do not understand the meaning of the question, n (%)	10 (5.6)	1 (3.6)	7 (12.5)	1 (2.0)	1 (2.4)
				P value = 0.196	

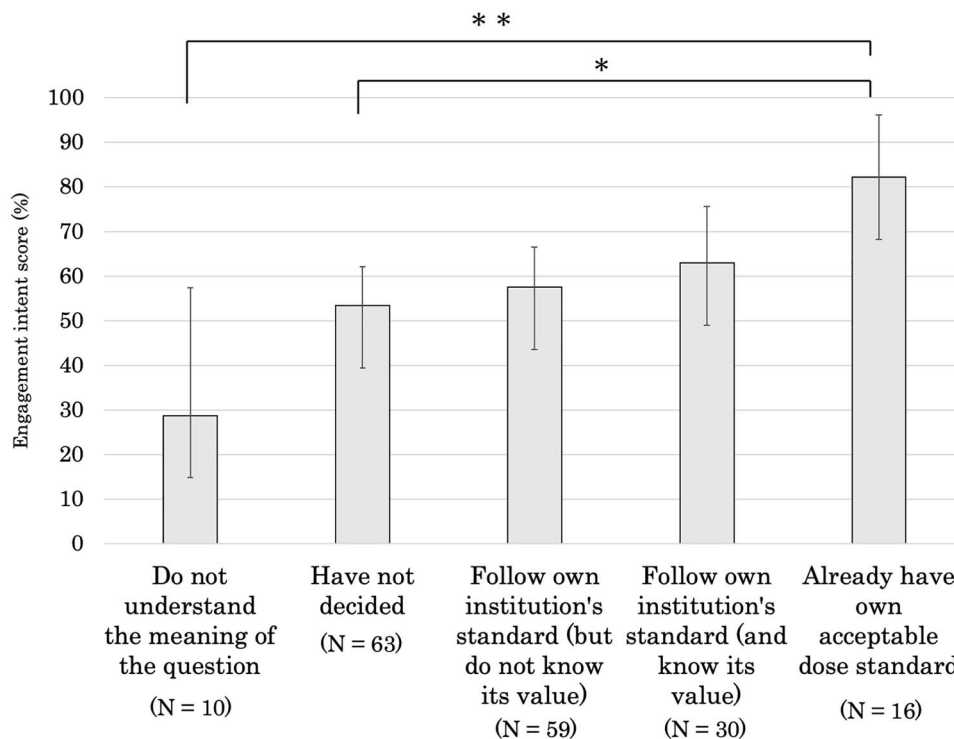
There were no differences among the 4 groups in terms of distribution of awareness of personally acceptable radiation exposure doses.

younger Group A, ≤39 years old in nuclear disaster-affected area; younger Group N, ≤39 years old in non-affected area; older Group A, ≥40 years old in nuclear disaster-affected area; older Group N, ≥40 years old in non-affected area.

'Follow own institution's standard (and know its value),' 62.9; 'Follow own institution's standard (but do not know its value),' 57.6; 'Have not decided,' 53.3; and 'Do not understand the meaning of the question,' 28.8. Those who responded that they did not understand what the question meant may lack the basic radiation-related knowledge and experience (low radiation literacy) to answer the question.

Compared to the participants who had established a personal acceptable standard, participants who had not decided, or who did

not understand the meaning of the question had significantly lower intention to engage in nuclear disaster activities (Fig. 1). In contrast, no difference was observed in the EIS for those who followed the standard accepted by their institution compared with those who had not decided or who did not understand the meaning of the question. The difference between the two responses 'Already have own acceptable dose standard' and 'Follow own institution's standard' is that individuals who had acceptable dose standards could determine



**Fig. 1.** Comparison of engagement intent score according to the establishment of a personal radiation exposure dose. The bar graph shows the mean engagement intent score with standard error for each response. Compared to the 'Already have own acceptable dose standard' group, the intention to engage in a nuclear disaster activity was found to be significantly lower in participants who responded 'Haven't decided,' and 'Don't understand question meaning.' \*  $P < 0.05$ ; \*\*  $P < 0.01$ .

values autonomously by their own will (active attitude), whereas individuals who followed the institution's standard would be given values by others (passive attitude). This finding indicates that the behavior of determining standard values at one's discretion may influence EIS.

Past studies have reported a low level of intention to engage in nuclear disasters [3–6, 13]. There is a significant shortage of human resources in this field, and measures are needed to resolve this problem. Since respondents who had established an acceptable personal exposure dose had a higher intention to engage in nuclear disaster activities, education and awareness on nuclear disaster response preparedness may contribute to solving the shortage of willing first responders. Low radiation literacy is a major problem not only in the medical profession but also in other professions. Past studies revealed that decontamination workers were anxious about their work owing to low radiation literacy and required proper knowledge and education to reduce anxiety [14, 15]. Therefore, dispelling anxiety and fear through education can help persons interested in this field gain confidence and preparedness for nuclear disaster responses, including setting a personal acceptable exposure dose in advance.

In the future, establishing legal enforcement of dose management and improving the hazard responders' knowledge and skills should be considered. Specific reference values could not be identified for all institutions that set the standard in this study, but some of the institutions seemed to have appropriated the ICRP criteria (100 mSv

in 5 years). While setting limits in advance is important for institutions, setting such limits does not necessarily mean that medical staff must continue working until they reach this limit. It is more important that each individual to have their own acceptable range within the limit values set by their institution in advance. For example, if the institutional limits are set higher than the workers' acceptable standards, they will not be able to work efficiently. Conversely, if the institutional limits are set lower than the workers' acceptable standards, they will have to leave the job before reaching their own acceptable standards despite being able to work, thereby adversely affecting the overall quality of the job. Hence, it is essential to determine the acceptable dose for the workers in advance. There is no law forcing medical staff to complete life-saving activities even with radiation exposure, so exposure is based on individual conscience and sacrifice. Therefore, workers must set an upper limit of acceptable doses in advance, and education should be provided so that personnel who may respond to a nuclear disaster can make an informed decision in setting personal acceptable exposure standards.

#### LIMITATIONS

The questionnaire was sent to the 376 registered e-mail addresses on the mailing list; some people might have registered with more than one e-mail address. Therefore, the actual response rate was not verified, but we believe that the actual response rate would be higher than 47.3% (178/376).

## CONCLUSION

This study revealed that awareness of personally acceptable doses of radiation exposure in a nuclear disaster response is closely associated with the intention to engage in nuclear disaster response-related activities. Therefore, educating potential responders to a nuclear disaster about personal exposure may help increase their intention to engage in emergency responses and improve their preparedness and response efficiency.

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## ETHICAL STATEMENT

This study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Fukushima Medical University (approval number: 2020-130).

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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