Journal of Radiological Protection

Official journal of the Society for Radiological Protection

PAPER • OPEN ACCESS

Risk communication regarding radiation exposure by experts using two concepts of regulatory science and ALARA

To cite this article: Yoshitoku Yoshida 2023 *J. Radiol. Prot.* **43** 011508

IOP Publishing J. Radiol. Prot. 43 (2023) 011508 https://doi.org/10.1088/1361-6498/acb274

Journal of Radiological Protection

CrossMark

OPEN ACCESS

RECEIVED
31 August 2022

REVISED
16 December 2022

ACCEPTED FOR PUBLICATION
12 January 2023

PUBLISHED
31 January 2023

PAPER

Risk communication regarding radiation exposure by experts using two concepts of regulatory science and ALARA

Yoshitoku Yoshida

Faculty of Medical Sciences, Shubun University, 6 Nikko-cho, Ichinomiya, Japan

E-mail: yoshida.yo@subun.ac.jp

Keywords: as low as reasonably achievable (ALARA), regulatory sciences, risk communication, perception gap, the Great East Japan Earthquake

Abstract

In the Tohoku region of Japan, risk communication programs on radiation exposure are of great importance, especially with respect to reducing the stress and anxiety among those affected by radiation exposure. Although the concepts of 'as low as reasonably achievable' (ALARA) and regulatory sciences (RS) were very important for the smooth operation of risk communication among a wide range of stakeholders, our previous research showed that only 23.5% and 16.5% of medical doctors in Japan had an accurate awareness of them, respectively. To make risk communication more effective, this study examined the levels of awareness of the concepts of ALARA and RS among academic experts in Japan and compared their level of awareness of technical terms regarding radiation to that of the expected level for a layperson. This study also showed that, even among faculty working at graduate schools in Japan, only 29.8% and 39.4% had an accurate knowledge of ALARA and RS. To improve the knowledge of laypeople and experts on these concepts, they should be added to the primary education curriculum. This study demonstrated that among experts in many academic fields, a significant range of estimates existed of lay knowledge of technical terms regarding radiation. The highest scores were assigned by faculty in the field of humanities. Thus, before conducting risk communications, experts from all fields should identify the expected level of awareness among laypeople on the topic. In addition, risk communications regarding radiation should be conducted by academic experts and healthcare professionals together with facilitators or lecturers.

1. Introduction

On 11 March 2011, the Great East Japan Earthquake hit the Tohoku region of Japan, causing a major accident at a nuclear power plant. Reporting by the Japanese Reconstruction Agency as of March 2022 indicates that 37 000 evacuees are still unable to return to their homes in Tohoku due to the incomplete reconstruction [1]. Immediately following the disaster, a range of stakeholders in Tohoku released risk communications for residents in the devastated region. In particular, doctors, nurses, and pharmacists, along with other healthcare professionals, have been taking part in risk communication.

The efficacy of risk communications has previously been evaluated in terms of possibilities of enhancing the effectiveness of risk communications that followed the Great East Japan Earthquake in Tohoku [2–6]. The authors of this article previously conducted research on the evaluation of risk communication and the degree of awareness of technical terms regarding radiation in six prefectures: Fukushima and Miyagi, which were hardest hit by the Great East Japan Earthquake and the consequent damage; Hiroshima and Nagasaki, which had been hit by atomic bombs; and Tokyo and Aichi, as controls [7]. We found that Fukushima Prefecture, followed by Miyagi Prefecture, had a significantly higher level of understanding than Aichi Prefecture, and we also found reported that residents in the disaster-stricken areas had obtained the necessary information and were proactive about their understanding of risk.

We also found that the two abbreviations, 'as low as reasonably achievable' (ALARA) and regulatory sciences (RS), are central for smooth risk communication. However, we also found that medical professionals, including doctors as instructors, did not understand these two concepts very well [8].

The International Commission on Radiological Protection defines ALARA as 'the principle of optimization of protection: the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors' [9]. Because ALARA takes into account economic and social factors, it has attracted some controversy regarding its effectiveness. With reference to the experiences of the Fukushima Daiichi Nuclear Power Plant accident, the International Radiation Protection Association has found that ALARA is a globally accepted concept, and the principle of optimization is a central dogma for radiation protection, as well as being the most important factor in avoiding radiation exposure [10].

In 1987, Dr Mitsuru Uchiyama proposed the concept of RS, which refers to a fit with the technological and scientific accomplishments of a community. This concept is used in establishing standard values from the perspective of current scientific and technological accomplishments. Recently, RS has come into wider use globally as a key concept that defines how much risk can be tolerated within the range allowable by safety regulations in areas of risk, especially in the field of drug approval regulations [11, 12].

In risk communication in Japan, both healthcare professionals and experts in a range of academic fields play crucial roles in the communication of risk as instructors and/or counselors [13]. This study examined the level of awareness of ALARA and RS by experts in academia. It also investigated differences among experts with respect to the layperson's awareness of 20 medical terms regarding radiation and experts' perceptions of needs for the public in risk communication to compare this with the needs of the public.

This study is the third of three in a sequence making up a larger study.

The title of the first study was 'Level of perception of technical terms related to the effect of radiation to human body by residents of Japan,' conducted from 13 to 19 February 2014 [7]. Demographic data pertaining to the residents of Miyagi, Fukushima, Tokyo, Aichi, Hiroshima, and Nagasaki Prefectures were the subjects of this study. A sample size of 160 was determined for each prefecture. The highest recognition levels were reported by respondents from Fukushima (17 items). Those from Miyagi had the second-highest levels (10 of 17 terms); the second-highest recognition levels for the remaining seven terms were marked by the respondents of Tokyo. Respondents in the Tohoku region had superior recognition of the technical terminology relevant to the effects of radiation on the human body.

The title of the second study was 'Medical staff perceptions of risk communication needs for the public and comparison with the needs expressed by the public' [8]. Demographics were collected from doctors, pharmacists, and nurses from all over Japan and compared to the data gathered from laypeople from the first study. In total, 170 medical doctors, 84 pharmacists, and 246 nurses were selected from all over Japan from 12 to 17 August 2016. The results showed differences between the public perception of risks and what the belief in the perception of risk was among medical workers. Only 23.5% and 16.5% medical doctors had an accurate perception of ALARA and RS in Japan, respectively.

2. Materials and methods

2.1. Study population and design

On 14 July 2016, this study was approved by Shubun University Ethics Committee prior to conducting research (approval number: 28SR2). The research was conducted through a contract with NTT Com Online Marketing Solution Co., Ltd, using an internet survey maintained by them. The monitors were registered with an internet survey company, along with basic information, including their gender, location of residence, and so on.

In total, 104 faculty members of graduate schools, 169 faculty members of universities, 58 teachers of college/vocational schools, and 1094 laypersons were selected from all over Japan, making 110% of the total amount intended. A two-step method was used to collect data from the experts. After excluding imperfect samples (as assessed by the contracting survey company), the results of the questionnaires were submitted to us. The research period was 7–27 August 2018.

2.2. Questionnaires and analyses

Questionnaires were composed incorporating respondent demographic information, how often the respondent had participated in a risk communication regarding the effects of radiation on the human body, the respondent's level of awareness of 20 medical terms related to radiation, the level of awareness of the meanings of eight medical issues related to radiation, the necessity of knowledge to be shared in risk communications, information sources related to radiation, and the practitioner's assessment of the reliability of the layperson and the reliability of the government of Japan, followed by information on risk avoidance behavior related to radiation.

The scoring of the answers was given on a scale of 1–5; for questions related to the respondent's own knowledge, for instance, the scale included 1, 'I have no idea'; 3, 'I cannot say for sure whether I know'; and 5, 'I know very well.'

3. Results

Table 1 presents the demographic information of the respondents. First of all, a statistically significant difference in age was seen between male and female faculty. Statistically significant differences were also observed across disciplines between male and female faculty at graduate schools, as well as between male and female teachers at college/vocational schools. A statistically significant difference also existed in age and education between male and female lay individuals.

With reference to factors related to the awareness of the ALARA across experts and laypersons, based on the unadjusted results of the analysis, a statistically significant association was observed with respect to having knowledge, as seen in table 2. Those who were male and a faculty member of a graduate school, or a faculty member of a university, were more likely to 'know,' compared with those who were female, and a layperson ($OR = 1.943$, 95%CI 1.302–2.901, $p = 0.001$; $OR = 4.737$, 95%CI 2.954–7.597, $p = 0.000$; $OR = 2.606$, 95%CI 1.676–4.050, $p = 0.000$, for female and laypersons, respectively). After adjusting for gender, age, and lay or expert status, also male, and a faculty member of a graduate school, and a faculty member of a university was related with a significant association with 'know' (adjusted $OR = 1.761$, 95%CI 1.150–2.698, $p = 0.009$; adjusted $OR = 3.833$, 95%CI 2.348–6.259, $p = 0.000$; adjusted $OR = 2.366$, 95%CI 1.512–3.701, $p = 0.000$) compared with female and laypersons as references, respectively.

In relation to the awareness of the RS concept by experts and laypersons, a statistically significant association existed for knowing in the unadjusted analysis, as shown in table 3. Those who were male, and a faculty member of a graduate school, university, or a college/vocational school, were more likely to 'know,' compared with those who were female and a layperson ($OR = 2.553$, 95%CI 1.673–3.896, $p = 0.000$; $OR = 8.249$, 95%CI 5.273–12.994, $p = 0.000$; $OR = 3.311$, 95%CI 2.140–5.121, $p = 0.000$; $OR = 2.328$, 95%CI 1.104–4.911, $p = 0.026$), respectively. After adjusting for gender, age, a layperson or institute of experts, also male, and a faculty member of a graduate school, university, or a college/vocational school were related with a significant association with 'knowing' (adjusted $OR = 1.858$, 95%CI 1.185–2.915, $p = 0.007$; adjusted $OR = 7.363$, 95%CI 4.580–11.838, $p = 0.000$; adjusted $OR = 3.224$, 95%CI 2.067–5.029, $p = 0.000$; adjusted $OR = 2.270$, 95%CI 1.064–4.842, $p = 0.034$, for female and a layperson, respectively).

In our previous work, we evaluated the contexts 'by doing risk avoidance behavior based on the criteria made a definition by the government, citizens can correctly avoid health impacts,' and 'considering the uncertainty of risk assessment, citizens should prevent risk on their own in the case of the Great East Japan Earthquake' for healthcare professionals and laypersons. We also collected data on the abovementioned contexts. For 'by doing risk avoidance behavior based on the criteria made a definition by the government, citizens can correctly avoid health impacts,' in an unadjusted analysis, a statistically significant association existed between "agree" and, with among "Layperson or Institute of Experts" as shown in table 4. Professors at graduate schools were more likely to 'agree,' than laypeople among those who were faculty members ($OR = 1.674$, 95%CI 1.085–2.583, $p = 0.020$). After adjusting for gender, lay or expert status, only faculty of graduate schools had a significant agree response (adjusted $OR = 1.679$, 95%CI 1.075–2.623, $p = 0.023$, for female and a layperson, respectively). For self-risk avoidance behavior related to the Great East Japan Earthquake, in the unadjusted analysis result, no statistically significant associations existed with responses of 'agree' (data not shown).

Table 5 presents the differences among ten knowledge items shared in risk communication; four of the ten were significant. For instance, a statistically significant difference appeared among graduate school faculty, university faculty, college/vocational school instructors, and laypeople with respect to the highest, and 3–5 awareness levels out of ten aspects, such as 'scientific facts, effects of radiation on children, providing the basis for standards, and validation of standards.' Knowledge of scientific facts was claimed by 82.7%, 81.1%, 69.0% and 65.4% of faculty at graduate schools, faculty at universities, instructors at college/vocational schools and laypeople, respectively. The knowledge of the effects of radiation on children, was claimed by 74.0%, 69.8%, 62.1%, and 61.7% of the same groups, respectively. The knowledge of setting rules for standards was claimed by 75.0%, 71.0%, 67.2%, and 62.5% of the same groups, respectively. Knowledge of validation of standards was claimed by 76.9%, 69.2%, 65.5%, and 62.3% of the same groups, respectively.

Table 6 showed statistically significant differences for one of the eight information sources related to radiation among respondents: 64.4% of faculty of graduate schools took academic journals/technical books to be a resource, followed by the internet (43.3%), forum/meeting style of risk communication (44.2%),

Table 1. Demographic characteristics of respondents.

Institute		Graduate school Gender Male ($n = 98$)	Graduate school Gender Female ($n = 6$)	χ^2test	University Gender Male ($n = 128$)	University Gender Female (n = 41)	χ^2test	College/Vocational school Gender Male ($n = 45$)	College/Vocational school Gender Female ($n = 13$)	χ^2test			A layperson Gender Male ($n = 694$)	A layperson Gender Female ($n = 400$)	χ^2test
Age	20–29	0(0.0%)	0(0.0%)	0.617	11(8.6%)	4(9.8%)	0.029	1(2.2%)	2(15.4%)	0.586	Age	20–29	12(1.7%)	24(6%)	0.000
	30–39	13(13.3%)	2(33.3%)		15(11.7%)	7(17.1%)		5(11.1%)	1(7.7%)			30–39	56(8.1%)	72(18%)	
	40–49	36(36.7%)	1(16.7%)		34(26.6%)	13(31.7%)		19(42.2%)	6(13.3%)			40–49	151(21.8%)	122(30.5%)	
	50–59	32(32.7%)	2(33.3%)		47(36.7%)	12(29.3%)		10(22.2%)	2(15.4%)			50–59	225(32.4%)	110(27.5%)	
	60 or	15(15.3%)	1(16.7%)		28(21.8%)	4(9.8%)		9(20.0%)	2(15.4%)			60–69	176(25.4%)	54(13.5%)	
	70 or more	2(2.0%)	0(0.0%)		3(2.3%)	1(2.4%)		1(2.2%)	0(0.0%)			70 or more	74(10.7%)	18(4.5%)	
Fields	Natural Science (Physics/Chemistry /Biology) Formal Chemistry (Mathematics/Statistics)	41(41.8%)	2(33.3%)	0.043	27(21.1%)	8(19.5%)	0.460	4(8.8%)	0(0.0%)	0.076	Education level	Junior high school	17(2.4%)	6(1.5%)	0.000
	Social Science (Politics, Economics, etc)	15(15.3%)	0(0.0%)		29(22.7%)	8(19.5%)		14(31.1%)	3(23.1%)			High school	213(30.7%)	124(31%)	
	Humanities (Philosophy, Humanity, Language)	8(8.2%)	1(16.7%)		28(21.9%)	13(31.7%)		6(13.3%)	1(7.7%)			College/Vocational school	66(9.5%)	130(32.5%)	
	Applied Science (Engineering, Agriculture, Medicine, Pharmacy, etc)	34(34.7%)	2(33.3%)		40(31.3%)	9(22.0%)		19(42.2%)	5(38.5%)			University	357(51.4%)	132(33%)	
	Others (design, music, etc)	0(0.0%)	1(16.7%)		4(3.1%)	3(7.3%)		2(4.4%)	4(30.8%)			Graduate school	41(5.9%)	8(2%)	
											Income (JPY)[a]	Less than 2000 000	112(16.1%)	46(11.5%)	0.58
												2000 000–4000 000	165(23.8%)	100(25%)	
												4000 000–6000 000	147(21.2%)	101(25.3%)	
												6000 000–8000 000	106(15.3%)	74(18.5%)	
												⩾8000 000	164(23.6%)	79(19.8%)	

[a] As of 20 October 2022, 1 USD is 149.88 JPN.

Table 2. Odds ratios (OR) and 95% confidence intervals (CI) for the awareness of the ALARA concept.

		Know[a]/*N* (%)	Crude OR (95% CI)[b]	*p*	Adjusted OR (95% CI)[c]	*p*
Gender	Female	33/460 (7.2%)	1 (Reference)		1 (Reference)	
	Male	126/965 (13.1%)	1.943(1.302–2.901)	0.001	1.761(1.150–2.698)	0.009
Age	20–29	5/44 (11.4%)	1 (Reference)		1 (Reference)	
	30–39	23/171 (13.5%)	1.212 (0.433–3.393)	0.714	0.879 (0.308–2.511)	0.809
	40–49	53/382 (13.9%)	1.257 (0.474–3.332)	0.646	0.851 (0.314–2.309)	0.752
	50–59	47/440 (10.7%)	0.933 (0.350–2.483)	0.889	0.618 (0.226–1.690)	0.349
	60–69	25/289 (8.7%)	0.739 (0.267–2.043)	0.559	0.502 (0.117–1.430)	0.197
	⩾70	6/99 (6.1%)	0.503 (0.145–1.746)	0.279	0.396 (0.111–1.411)	0.396
Layperson or Institute of Experts	Layperson	90/1097 (8.2%)	1 (Reference)		1 (Reference)	
	Graduate school	31/104 (29.8%)	4.737 (2.954–7.597)	0.000	3.833 (2.348–6.259)	0.000
	University	32/169 (18.9%)	2.606 (1.676–4.050)	0.000	2.366 (1.512–3.701)	0.000
	College	6/58 (10.3%)	1.287 (0.538–3.079)	0.570	1.087 (0.450–2.625)	0.852

[a] 1 means 'I do not know at all'; 3 indicates 'I cannot tell clearly whether I know'; and 5 indicates 'I know very well'. In analyzing, 4 and 5 out of 1–5 were used as 'I know'.

[b] Crude odds ratio and 95% confidence interval.

[c] Adjusted odds ratio for gender, age, occupation, participation in clinical trial and 95% confidence interval.

Table 3. Odds ratios (OR) and 95% confidence intervals (CI) for the awareness of the concept of RS.

		Know[a]/N (%)	Crude OR (95% CI)[b]	*p*	Adjusted OR (95% CI)[c]	*p*
Gender	Female	28/460 (6.1%)	1 (Reference)		1 (Reference)	
	Male	137/965 (14.2%)	2.553(1.673–3.896)	0.000	1.858 (1.185–2.915)	0.007
Age	20–29	4/44 (9.1%)	1 (Reference)		1 (Reference)	
	30–39	19/171 (11.1%)	1.250 (0.403–3.881)	0.700	0.792 (0.247–2.546)	0.696
	40–49	45/382 (11.8%)	1.335 (0.456–3.908)	0.598	0.768 (0.254–2.325)	0.641
	50–59	55/440 (12.5%)	1.429 (0.492–4.148)	0.512	0.866 (0.288–2.603)	0.797
	60–69	29/289 (10.0%)	1.115 (0.372–3.341)	0.845	0.705 (0.227–2.193)	0.546
	⩾70	13/99 (13.1%)	1.512 (0.464–4.928)	0.493	1.257 (0.370–4.269)	0.714
Layperson or Institute of Experts	A layperson	80/1097 (7.3%)	1 (Reference)		1 (Reference)	
	Graduate school	41/104 (39.4%)	8.249 (5.273–12.994)	0.000	7.363 (4.580–11.838)	0.000
	University	35/169 (20.7%)	3.311 (2.140–5.121)	0.000	3.224 (2.067–5.029)	0.000
	College	9/58 (15.5%)	2.328 (1.104–4.911)	0.026	2.270 (1.064–4.842)	0.034

[a] 1 means 'I do not know at all'; 3 indicates 'I cannot tell clearly whether I know'; and 5 indicates 'I know very well'. In analyzing, 4 and 5 out of 1–5 were used as 'I know'.

[b] Crude odds ratio and 95% confidence interval.

[c] Adjusted odds ratio for gender, age, occupation, participation of clinical trial and 95% confidence interval.

N: number of subjects.

television (44.2%), and radio (22.1%). In all, 74.0% of faculty of graduate schools thought that academic journals/technical books were trustworthy, followed by forum/meeting style of risk communication (59.6%), public relations by the central government (40.4%), and the internet, which was marked the lowest (17.3%). In all, 53.3% of university faculty considered the internet to be a resource, followed by newspapers (50.9%), television (49.7%), and radio, which received the lowest percentage (18.9%). In all, 66.3% of university faculty thought that academic journals/technical books were trustworthy, followed by forum/meeting style of risk communication (45.6%), newspapers (36.1%), and radio again ranking lowest (23.7%). In all, 60.3% of college/vocational instructors took television as a resource, following the internet (53.4%), newspapers (50.0%), and radio, with the lowest percentage (19.0%). In all, 60.3% of college/vocational instructors thought that academic journals/technical books were trustworthy, followed by a forum/meeting style of risk communication (53.4%), public relations by the central government (36.2%), and radio (19.0%). In all, 51.6% of laypeople considered television to be a resource, followed by newspapers (45.4%), the internet (44.5%), and radio, with the lowest percentage (23.6%). In all, 47.1% of laypeople thought that academic

Table 4. Odds ratios (OR) and 95% confidence intervals (CI) for difference among experts and laypersons in terms of 'agree' regarding the context that "by performing risk avoidance behavior according to the criteria defined by the government, citizens can sufficiently avoid health effects".

		Agree[a]/*N* (%)	Crude OR (95% CI)[b]	*p*	Adjusted OR (95% CI)[c]	*p*
Gender	Male	234/965 (24.2%)	1 (Reference)		1 (Reference)	
	Female	110/460 (23.9%)	0.982(0.757–1.273)	0.890	1.009 (0.766–1.328)	0.951
Age	20–29	13/44 (29.5%)	1 (Reference)		1 (Reference)	
	30–39	47/171 (27.5%)	0.904 (0.436–1.875)	0.786	0.862 (0.414–1.796)	0.692
	40–49	94/382 (24.6%)	0.778 (0.391–1.549)	0.475	0.763 (0.367–1.476)	0.388
	50–59	101/440 (23.0%)	0.710 (0.358–1.409)	0.328	0.681 (0.340–1.365)	0.279
	60–69	68/289 (23.5%)	0.734 (0.364–1.481)	0.388	0.718 (0.351–1.468)	0.363
	⩾70	21/99 (21.2%)	0.642 (0.286–1.439)	0.282	0.660 (0.290–1.501)	0.322
Layperson or Institute of Experts	A layperson	246/1097 (22.5%)	1 (Reference)		1 (Reference)	
	Graduate school	34/104 (32.7%)	1.674 (1.085–2.583)	0.020	1.679 (1.075–2.623)	0.023
	University	49/169 (29.0%)	1.408 (0.981–2.020)	0.064	1.403 (0.974–2.021)	0.069
	College	15/58 (25.9%)	1.202 (0.657–2.201)	0.550	1.182 (0.642–2.174)	0.592

[a] 1 means 'I do not agree at all'; 3 indicates 'I cannot tell clearly whether I agree or not'; and 5 indicates 'I agree very much.' In analyzing, 4 and 5 out of 1–5 were used as 'I agree'.

[b] Crude odds ratio and 95% confidence interval.

[c] Adjusted odds ratio for gender, age, occupation, Participation of clinical trial and 95% confidence interval.

N: number of subjects.

Table 5. Difference in the percentage of 'Need' of the knowledge which should be delivered at the forum style risk communication among experts and laypersons.

	Graduate school ($n = 104$)	University ($n = 169$)	College ($n = 58$)	A layperson ($n = 1094$)	
Item	Need[a] (%)	Need (%)	Need (%)	Need (%)	χ^2test
Scientific facts	82.7	81.1	69.0	65.4	0.000
Uncertainty of radiation effects	67.3	60.4	60.3	55.2	0.073
Radiation effects on children	74.0	69.8	62.1	61.7	0.024
Setting the basis for the standards	75.0	71.0	67.2	62.5	0.017
Validity of the standards	76.9	69.2	65.5	62.3	0.012
Recommendation of avoidance behavior	67.3	63.9	55.2	59.8	0.289
Risk of radiation effects	71.2	66.9	74.1	68.6	0.714
Effectiveness of decontamination as a radiation countermeasure	68.3	66.9	63.8	64.5	0.829
Effectiveness of food standards as a radiation countermeasure	74.0	66.3	70.7	65.3	0.283
The effectiveness of the standards of space dose of radiation as a countermeasure	68.3	62.1	56.9	61.5	0.480

[a] A score of 1 indicated 'I do not need it'; 3 indicated 'I cannot tell clearly whether I need it'; and 5 indicated 'I need it very well.' The most appropriate number from 1 to 5 was selected and was termed 'the knowledge which should be delivered at the forum-style risk communication.' For the analyses, 4 and 5 indicated 'I need'.

journals/technical books were trustworthy, followed by a forum/meeting style of risk communication (39.8%), newspapers (38.1%), and radio (25.3%).

Regarding factors related to laypeople's expected level of awareness of 20 medical terms related to radiation, in the unadjusted analysis, a statistically significant association existed with the expectation that a layperson would know this term in table 7. Experts in humanities were more apt to think that a layperson would know than those who were experts in natural science ($OR = 2.781$, 95%CI 1.314–5.883). After adjusting for gender, age, institute of experts, and field of expertise, the field of humanities showed a significant association with the judgment that a layperson would know (adjusted $OR = 2.910$, 95%CI 1.317–6.428, $p = 0.008$).

Table 6. Difference in the percentage of 'Agree' on the sources of information regarding radiation and its reliability among experts and laypersons.

Source	Graduate school (n = 104)	University (n = 169) Agree[a] (%)	College (n = 58) Agree (%)	A layperson (n = 1094) Agree (%)	χ^2 test
Forum/meeting of risk communication	44.2	33.7	27.6	32.1	0.067
TV	44.2	49.7	60.3	51.6	0.241
Newspapers	39.4	50.9	50.0	45.4	0.268
Radio	22.1	18.9	15.5	23.6	0.311
Internet	43.3	53.3	53.4	44.5	0.105
Public relations by the local government	35.6	32.0	27.6	36.0	0.461
Public relations by the central government	37.5	33.7	25.9	32.5	0.492
Academic journals/technical books	64.4	48.5	31.0	30.6	0.000
Reliability					
Forum/Meeting of risk communication	59.6	45.6	53.4	39.8	0.000
TV	22.1	27.8	22.4	32.8	0.040
Newspapers	32.7	36.1	34.5	38.1	0.669
Radio	22.1	23.7	19.0	25.3	0.632
Internet	17.3	26.6	25.9	26.0	0.271
Public relations by the local government	39.4	30.8	29.3	36.6	0.284
Public relations by the central government	40.4	29.6	36.2	34.8	0.321
Academic journals/technical books	74.0	66.3	60.3	47.1	0.000

[a] Answer 1 indicated 'I do not agree it'; 3 indicated 'I cannot tell clearly whether I agree on it'; and 5 indicated 'I agree it very well'. The most appropriate number from 1 to 5 was selected and was termed 'the sources of information regarding radiation and its reliability and the reliability of the central government and risk avoidance behavior regarding radiation.' For the analyses, 4 and 5 indicated 'I agree'.

Table 7. Odds ratios (OR) and 95% confidence intervals (CI) for difference among experts with respect to a layperson's awareness level of the 20 medical terms regarding radiation.

		Know[a]	N (%)	Crude OR (95% CI)[b]	p	Adjusted OR (95% CI)[c]	p
Gender	Male	77/271	(28.4)	1 (Reference)		1 (Reference)	
	Female	15/60	(25.0)	0.840 (0.442–1.595)	0.594	0.779 (0.384–1.582)	0.489
Age	20–29	1/8	(12.5)	1 (Reference)		1 (Reference)	
	30–39	8/43	(18.6)	1.600 (0.172–14.90)	0.680	1.080(0.110–10.65)	0.948
	40–49	30/109	(27.5)	2.658 (0.314–22.53)	0.370	1.867 (0.209–16.70)	0.576
	50–59	30/105	(28.6)	2.800 (0.330–23.74)	0.345	1.795 (0.198–16.28)	0.603
	60–69	20/59	(33.9)	3.590 (0.413–31.24)	0.247	2.252 (0.241–21.06)	0.477
	⩾70	3/7	(42.9)	5.250 (0.400–68.95)	0.207	3.700 (0.264–51.79)	0.331
Institute	College	14/58	(24.1)	1 (Reference)		1 (Reference)	
	University	50/169	(29.6)	1.321 (0.665–2.623)	0.427	1.328 (0.642–2.745)	0.444
	Graduate school	28/104	(26.9)	1.158(0.552–2.430)	0.698	1.398 (0.627–3.118)	0.413
Field	Natural Science	17/82	(20.7)	1 (Reference)		1 (Reference)	
	Social science	20/69	(29.0)	1.561 (0.741–3.288)	0.242	1.604 (0.737–3.493)	0.234
	Humanities	24/57	(42.1)	2.781 (1.314–5.883)	0.007	2.910 (1.317–6.428)	0.008
	Applied science	26/109	(23.9)	1.198 (0.599–2.393)	0.609	1.231 (0.604–2.507)	0.567
	Other	5/14	(35.7)	2.124 (0.629–7.171)	0.225	2.618 (0.702–9.763)	0.152

[a] 1 means 'I do not see or hear it'; 3 means 'I cannot tell clearly whether I see or hear it'; 5 means 'I often see or hear it.' In analyzing, 4 and 5 out of 1–5 were used as 'I know.' To evaluate the crude odds ratio (OR) and adjusted OR in terms of the awareness of level of a layperson's awareness of the 20 technical terms regarding radiation among experts, the five-point Likert scores of 20 medical terms were totaled, and 61 was used as an index of cut-off, in order that a total score ⩾ 61 for level of awareness of 20 medical terms related to radiation represented that 'a layperson knows.' The 20 technical terms regarding radiation are as follows; x-ray, radioactive substance, WHO (World Health Organization), radioactive cesium, external radiation exposure, internal radiation exposure, IAEA (International Atomic Energy Agency), Sievert, half-life, Becquerel, acute radiation exposure, radioactive strontium, natural background radiation, low-dose radiation exposure, α-ray, β-ray, neutron ray, γ-ray, the law concerning the prevention of radiation hazards due to radioisotopes and others of Japan and ICRP (International Commission on Radiological Protection).

[b] Crude odds ratio and 95% confidence interval.

[c] Adjusted odds ratio for gender, age, occupation, Participation of clinical trial and 95% confidence interval.

N: number of subjects.

With respect to the layperson's expected level of awareness of the meanings of eight medical issues related to radiation by experts, in the unadjusted analysis, no significant differences were found based on socio-demographic parameters (data not shown).

4. Discussion

Both ALARA and RS are very important for effective risk communication among many kinds of stakeholders. However, our previous study demonstrated that only low percentages of medical doctors in Japan had a correct awareness of the concepts of ALARA and RS, 3.5% and 16.5%, respectively [8]. The results of this research demonstrate that even faculty at graduate schools in Japan, experts in many kinds of fields, have an insufficient knowledge of ALARA and RS. Only 29.8% and 39.4%, respectively, had an adequate knowledge of ALARA and RS. Therefore, to rectify this, both experts or healthcare professionals and laypeople should receive instruction on these concepts in primary education, accompanied by plain explanations.

In total, 32.7% of graduate school faculty agreed that 'by doing risk avoidance behavior based on the criteria made a definition by the government, citizens can correctly avoid health impacts,' showing a statistically significant difference among experts and laypersons. No statistically significant difference was seen between experts and laypersons with respect to the item 'in considering the uncertainty of risk assessment, citizens should prevent from the risk at their own risk in the case of the Great East Japan Earthquake.' In contrast, our previous study showed that about one fifth of healthcare professionals and laypeople agreed that 'by doing risk avoidance behavior based on the criteria made a definition by the government, citizens can correctly avoid health impacts' [8]. A statistically significant difference existed in the self-risk avoidance behavior related to radiation. The highest percentage (54.0%) were identified by laypeople, in relation to 'considering the uncertainty of risk assessment, citizens should prevent from the risk.' Even among experts in healthcare and academia, the reliability of central government showed different aspects. Therefore, both should collaborate as facilitators and/or lecturers on the same forum-style risk communications.

Lochard noted that dialogues regarding radiation exposure were focused on the interest of the public and not on what the healthcare professionals considered to be the public interest [14]. This implies a difference between the groups. In relation to knowledge that should be shared in risk communications based on the results of this study, the highest-interest item for laypeople was the risk of radiation effects (68.6%), followed by scientific facts (65.4%), effectiveness of food standards against radiation effects (65.3%); among the ten items, the uncertainty of radiation effects (55.2%) was the least interesting. Our previous work also indicated that for the layperson, the uncertainty of the radiation effects was the least interesting, possibly because laypeople tended to report that uncertainty produced anxiety [8]. On the other hand, graduate school faculty thought that of most interest to the public was scientific facts (82.7%), followed by standards validation (76.9%) and setting rules for standards (75.0%). University faculty thought that scientific facts (81.1%) were most interesting, followed by setting rules for standards (71.0%). College/vocational instructors thought that of most interest was risk of radiation effects (74.1%), followed by effectiveness of food standards against radiation effects (70.7%). These results demonstrate that there were important differences between the public perception of risks and experts' belief in what the public's risk perception was. This study also demonstrated that experts should consider whether dialogue regarding radiation exposure is focused on the interest of the public to produce the most effective risk communication.

Hidaka *et al* found that the 'acquisition of correct knowledge of working environment management was related with anxiety over radiation exposure. The acquisition of the knowledge may help the reduction of physical health risks, it may even increase the mental health risk' [15]. That is, these seem to be risk explanations rather than risk communications. Following these findings, facilitators should take these differences into account when engaging in risk communication with the public.

Among graduate school faculty, academic journals and technical books were the most trusted source, followed by forums/meetings for risk communication and television. Additionally, academic journals/technical books, and risk communication had the highest values in terms of reliability. However, the reliability of academic journals/technical books (74.0%) among graduate school faculty was far from 100%, perhaps implying some skepticism among experts.

On the other hand, the reliance on academic journals/technical books among graduate school faculty is higher than among university faculty and college instructors. It seems that faculty of graduate schools were more familiar with accessing academic journal/technical books than university faculty, and college instructors. Our previous study showed that medical doctors responded similarly [8]. Experts and medical professionals should explain the necessary information to laypeople in the most concise and plain, but scientifically sound, way.

Academic experts in the humanities in academia exhibited the highest estimation of lay knowledge in terms of technical terms regarding radiation, with a statistically significant difference. Our previous study showed that medical doctors tended to overestimate lay knowledge of medical terms related to radiation relative to pharmacists and nurses [8]. In contrast, nurses were more likely to estimate that a layperson would know medical terms not related to radiation than pharmacists and medical doctors were [16–18].

Regarding communication between the patient and healthcare professionals, Hu called for a strategy to improve patient-provider communication and trust to improve patient acceptability of uncertainty in clinical work. Therefore, many fields' experts should check the awareness level of a layperson on a topic before engaging in risk communication [19].

Although web surveys are widely used in the medical sociology field in Japan, information related to the level of awareness of medical terms might not be obtained in an optimal way through a web survey compared with an interview survey. This is a limitation of this study, therefore.

Moriyama *et al* found that effective support increased the trust of older residents of restoration shelters regarding the involvement of scientists, including healthcare workers, in risk communications [20].

In conclusion, to improve knowledge of ALARA and RS among both experts/healthcare professionals and laypeople in Japan, the two concepts should be taught in the primary education curriculum with plain explanations. In addition, before conducting risk communication, all experts should endeavor to check the level of awareness of the topic among their lay audience.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Acknowledgments

This study was partially supported by JSPS KAKENHI Grant Number 16K09130 from the Japanese Society for the Promotion of Science.

Conflicts of interest

The authors declare that they have no conflicts of interest.

ORCID iD

Yoshitoku Yoshida https://orcid.org/0000-0002-0046-4193

References

[1] Reconstruction Agency of Japan Status of reconstruction and reconstruction efforts reported by reconstruction agency (available at: www.reconstruction.go.jp/english/topics/Progress_to_date/pdf/English_April_2022_genjoutorikumi.pdf) (Accessed 21 July 2022)
[2] Nakashima K, Orita M, Fukuda N, Taira Y, Hayashida N, Matsuda N and Takamura N 2015 Radiocesium concentrations in wild mushrooms collected in Kawauchi village after the accident at the Fukushima Daiichi nuclear power plant *PEERJ* **3** e1427
[3] Bromet E J 2014 Emotional consequences of nuclear power plant disasters *Health Phys.* **106** 206–10
[4] Goto A, Bromet E J and Fujimori K 2015 Immediate effects of the Fukushima nuclear power plant disaster on depressive symptoms among mothers with infants: a prefectural-wide cross-sectional study from the Fukushima health management survey *BMC Psychiatry* **15** 59
[5] Staudenherz A and Leitha T 2011 Medical preparedness in radiation accidents: a matter of logistics and communication not treatment! *Int. J. Occup. Environ. Med.* **2** 133–42
[6] Ohtsuru A *et al* 2015 Nuclear disasters and health: lessons learned, challenges, and proposals *Lancet* **386** 489–97
[7] Yoshida Y, Yoshida Y, Isogai E, Hayase T, Nakamura K, Saito M and Arizono K 2017 Level of perception of technical terms related to the effect of radiation to human body by residents of Japan *Environ. Health Prev. Med.* **22** 73
[8] Yoshida Y and Yoshida Y 2020 Medical staff perceptions of risk communication needs for the public and comparison with the needs expressed by the public *Radioprotection* **55** 199–206
[9] International Commission on Radiological Protection 2007 International Commission on Radiological Protection (ICRP) Publication 103
[10] Coates R and Czarwinski R 2018 IRPA consultation: is the system of protection 'fit for purpose' and can it be readily communicated? Views of the radiation protection professionals *J. Radiol. Prot.* **38** 440–55
[11] Poston J W Sr 2017 Fortieth Lauriston S. Taylor lecture: radiation protection and regulatory science *Health Phys.* **112** 193–8
[12] Hayashi Y 2009 Scientific basis for risk analysis of food-related substances with particular reference to health effects on children *J. Toxicol. Sci.* **34** SP201–7
[13] Sakoda A, Nomura N, Kuroda Y, Kono T, Naito W and Yoshida H 2021 Review of engagement activities to promote awareness of radiation and its associated risk amongst the Japanese public before and after the Fukushima Daiichi nuclear power plant accident *J. Radiol. Prot.* **41** 1258–87
[14] Lochard J, Schneider T, Ando R, Niwa O, Clement C, Lecomte J F and Tada J I 2019 An overview of the dialogue meetings initiated by ICRP in Japan after the Fukushima accident *Radioprotection* **54** 87–101

[15] Hidaka T, Kakamu T, Endo S, Kasuga H, Masuishi Y, Kumagai T, Sato S, Sasaki T and Fukushima T 2019 Association of anxiety over radiation exposure and acquisition of knowledge regarding occupational health management in operation leader candidates of radioactivity decontamination workers in Fukushima, Japan: a cross-sectional study *Int. J. Environ. Res. Public Health* **17** 228

[16] Yoshida Y, Yoshida Y, Motoyoshi T, Saito M, Saito A M and Hayase T 2013 Study of perception gaps in pharmaceutical terms and related issues between a lay people and medical practitioners. (in Japanese) *Nihon Eiseigaku Zasshi* **68** 126–37

[17] Yoshida Y and Yoshida Y 2014 Patient's recognition level of technical terms as estimated by pharmacists *Environ. Health Prev. Med.* **19** 414–21

[18] Yoshida Y and Yoshida Y 2015 Patients' level of medical term recognition as estimated by healthcare workers *Nagoya J. Med. Sci.* **77** 123–32

[19] Hu H L, Gong H Y, Wu X N and Wu X 2022 Effect of patient-provider communication on patient risk awareness: the moderating role of trust based on scenario experiment *Psych. J.* **2** 359–69

[20] Moriyama N, Iwasa H, Tsubokura M, Kuroda Y and Yasumura S 2019 Living in the restoration public housing after the Great East Japan earthquake correlates with lower subjective well-being of older adults *Int. J. Environ. Res. Public Health* **16** 2696