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Firefighters' and Emergency Medical Service Personnel's Knowledge and Training on Radiation Exposures and Safety: Results from a Survey

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Little is known about first responders' knowledge of radiation exposure and the training they receive regarding radiological events. Firefighters and emergency medical services (EMS) personnel were surveyed in July 2018 to February 2019 regarding their knowledge of radiation exposure and the radiological event training they had received. Knowledge was assessed using 15 true-false questions. Five types of radiological event training were assessed. A Mann-Whitney test assessed differences in training received by occupation. A linear regression identified predictors of knowledge scores. A total of 433 individuals completed the survey (response rate = 82.9%). Knowledge scores ranged from 5 to 13, with an average of 8.6. Predictors of knowledge included having received more training on radiological transportation incidents or improvised nuclear devices, and being a firefighter. About a quarter (23.6%, $n = 102$) had not received any of the 5 types of radiological event training. Firefighters received more training than EMS personnel except on nuclear reactor incidents. Only 14% had participated in a radiological event exercise. First responders' knowledge of radiation exposure and prevention measures is low, and many have received either no or very little training on radiological events. The lack of radiation exposure knowledge and radiological event training received, as identified in this study, could result in increased mortality rates. First responder agencies should provide additional radiological event training and exercise opportunities.

Keywords: Disaster, Prehospital, Emergency management, Radiation, Dirty bomb, Knowledge, Training

Radiation exposure can pose a serious health and safety risk, depending on the type of radiation or radioactive isotope(s) and the route and duration of exposure.[1] Firefighters and emergency medical services (EMS) personnel may be exposed to radiation during their routine work duties and need to be prepared to respond to a naturally occurring or man-made event involving a radiological material, including an industrial accident or a radiological terrorism event, such as a dirty bomb.[2-4] During a radiological incident, these first responders' roles include

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securing the scene, decontaminating victims when needed, and triaging and stabilizing patients.[3,5]

Radiological event training is recommended for all first responders, with the goals of preparing these professionals to protect themselves from radiation exposure during their work duties and minimizing the spread of radiation from contaminated sources to noncontaminated individuals, objects, or areas.[2,3,5-7] Pre-event training is designed to increase first responders' self-efficacy and comfort in working during a radiological event.[8] In addition, pre-event training has been found to be associated with an increased willingness to work during a radiological terrorism event, which will increase a community's resilience.[3,9]

Although radiological event training has been recommended for many years, very few studies have examined the extent to which first responders have received this training. A 2007 study conducted in Canada found that 63% of EMS personnel had received at least some training on radiological terrorism, but only 50% had actually donned personal protective equipment in the prior year.[10] A similar study in the United States in 2007 reported that only 30.8% of EMS personnel had received any training on radiological disasters.[8] Neither of these studies measured first responders' knowledge of radiation exposure or response, nor did they assess training related to naturally occurring radiological events. The purposes of this study were to examine the extent to which firefighters and EMS personnel had received training on naturally occurring and man-made radiological events, or participated in exercises involving multiple disaster scenarios, and to assess their knowledge of radiation exposure and prevention.

Methods

Firefighters and EMS professionals working at 2 first responder agencies in a midwestern greater metropolitan region were invited to complete an anonymous survey assessing their knowledge of radiation exposures and the radiation exposure training they had received. Individuals were recruited face-to-face before educational workshops and during on-site recruitment sessions at participating agencies; email recruitment was also used for 1 of the agencies. The survey was available both electronically and on paper.

Instrument

The questionnaire was based on research team member and EMS training staff expertise and previous studies examining terrorism risk perceptions.[11-14] Twelve researchers with expertise in radiation and radiological disasters assessed instrument content validity using a content validity index (CVI).[15] All survey questions had a CVI above 0.80, so none was deleted, though items were revised based on feedback from CVI panel members.[15] Five firefighters and 5 EMS personnel pilot tested the instrument for clarity and ease of use; feedback from pilot testers was used to finalize the questionnaire.

The final instrument contained 29 questions plus demographic items. Respondent knowledge was assessed using a set of 15 true-false questions related to the routes and health effects of ionizing radiation exposure and protective measures to prevent exposure. The knowledge questions fell into 3 categories of 5 items each: (1) radiation exposure protection measures, (2) radiation exposure health effects, and (3) decontamination procedures. Additional survey items included perceived risk from radiation exposure (1 item); perceived threat for radiological disasters in their geographical region in the next 5 years (2 items); the amount and type of previous radiation exposure training received (5 items); prior participation in disaster exercises (3 items); and perceived safety and self-efficacy in responding to a dirty bomb scenario (3 items).

Risk perception and perceived safety and self-efficacy questions were measured on a 5-point Likert-type scale (ie, strongly agree to strongly disagree). Exercise participation was dichotomous. Training was measured as none, ≤1 hour, 2 to 3 hours, or ≥4 hours.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) 25[16] was used for all analyses. Likert-scale questions were dichotomized, with strongly agree and agree recoded as "yes" and neutral, disagree, and strongly disagree recoded as "no." An overall knowledge score was calculated from the 15 true-false questions (possible score range: 0–15); a knowledge score was also calculated for each of the 3 knowledge subscales/categories (possible score range: 0–5). Descriptive statistics were conducted on all variables. A repeated-measures analysis of variance (ANOVA) was used to assess differences in knowledge scores among the 3 knowledge area categories. Chi-square tests were used to determine if there were differences in attitudes/beliefs and training received by occupation (ie, firefighters vs EMS personnel). A Mann-Whitney test assessed differences in training received by occupation. Multivariate linear regression with hierarchical variable entry was used to determine predictors of higher knowledge scores. First, univariate analysis was conducted, using demographic and attitude/belief variables. Only significant variables from univariate analyses were included in the multivariate analysis. Variables significant in univariate analysis that were nonsignificant in multivariate analysis were dropped from the model; only the final model is reported. A critical p value of .05 was used for all tests.

Results

In total, 522 individuals were approached for recruitment; 433 completed the survey (response rate = 82.9%).

A full list of participant demographics is provided in Table 1. Of the respondents, 64.2% ($n=278$) were firefighters and 35.8% ($n=155$) were EMS personnel (Table 1). Most of the respondents were male (89.6%, $n=386$) and worked full-time (99.1%, $n=429$; Table 1). Approximately three-quarters were white (76.8%, $n=318$), 16.7% ($n=69$) were black, and 6.4% ($n=27$) were Asian, Hispanic, or another race (Table 1). Most (66.7%, $n=289$) had received some college education or an associate's degree; about a quarter (23.3%, $n=101$) had a bachelor's degree or more (Table 1). Almost two-thirds (63.5%, $n=275$) had 11 or more years' of work experience in their field; 18.9% had 5 to 10 years' experience; 17.6% had 4 years of experience or less (Table 1).

Knowledge of Radiation Exposures and Safety

Respondents' overall knowledge scores ranged from 5 to 13 (out of 15 possible), with an average score of 8.6 (57%). The percentage of respondents who answered each knowledge item correctly is outlined by occupation in Table 2. Almost all respondents knew that the 3 recommended factors for reducing radiation exposure were time, distance, and shielding (97.0%, $n=420$); the personal protective equipment (PPE) worn by first responders is insufficient to block all types of radiation exposure (95.6%, $n=414$); exposure to high doses of radiation over a short period of time can result in acute radiation syndrome (92.8%, $n=402$); and the earliest symptoms of significant radiation exposure include nausea, vomiting, and headache (91.2%, $n=395$; Table 2). The knowledge questions missed by the most respondents were: full-body patient decontamination is not needed after radiation contamination (10.9%, $n=47$); the biggest threat at a dirty bomb site is from the explosion rather than the radioactive material (13.2%, $n=57$); first responders do not need to wear a self-contained breathing apparatus when responding to a radiation event to protect the lungs from exposure (27.7%, $n=120$); and doubling the distance from a radiation source will not reduce the exposure by half (34.6%, $n=171$; Table 2).

Table 1. Participant Demographics

Characteristic	*All Respondents* N = *433*[a] % (n)	*Firefighters* n = *278*[a] % (n)	*EMS* n = *155*[a] % (n)
Gender			
Male	89.6 (386)	99.3 (276)	70.1 (110)
Age			
18-30 years	14.5 (63)	7.2 (20)	27.7 (43)
31-40 years	32.8 (142)	31.7 (88)	34.8 (54)
41-50 years	27.0 (117)	29.1 (81)	23.2 (36)
≥51 years	25.6 (111)	32.0 (89)	14.2 (22)
Race			
White	76.8 (318)	72.1 (189)	84.9 (129)
Black	16.7 (69)	21.8 (57)	7.9 (12)
Asian	1.4 (6)	.8 (2)	2.6 (4)
Hispanic	1.4 (6)	1.5 (4)	1.3 (2)
Other/mixed	3.6 (15)	3.8 (10)	3.3 (5)
Education			
High school or less	9.9 (43)	12.6 (35)	5.2 (8)
Some college/2-year degree	66.7 (289)	64.0 (178)	71.6 (111)
Bachelor's degree or more	23.3 (101)	23.4 (65)	23.2 (36)
Marital status			
Married/committed (vs single/widowed)	69.3 (300)	74.8 (208)	59.4 (92)
Single or widowed	30.7 (133)	25.2 (70)	40.6 (63)
Have child ≤18 years in household	51.3 (222)	50.0 (139)	53.5 (83)
Employment status			
Full-time	99.1 (429)	99.3 (276)	98.7 (153)
Part-time	.9 (4)	.7 (2)	1.3 (2)
Years of work experience in field			
≤4 years	17.6 (76)	14.0 (29)	23.9 (37)
5-10 years	18.9 (82)	15.1 (42)	25.8 (40)
≥11 years	63.5 (275)	70.9 (197)	50.3 (78)

[a]Denominator varies due to missing/incomplete data.

Table 2. Firefighters' Versus Emergency Medical Services Personnel's Knowledge Regarding Radiation Exposure Risks and Prevention

Knowledge Question	*All Respondents* N = *433*	*Firefighter vs EMS* N = *433*		
		Firefighter n = *278*	*EMS* n = *155*	*Firefighter vs EMS*
	Answered Correctly % (n)	*Correct %* (n)	*Correct %* (n)	p-*value*[a]
Radiation Protective Measures Questions				
The 3 recommended factors for reducing radiation exposure are time, distance, and shielding. (T)	97.0 (420)	97.8 (272)	95.5 (148)	NS
The personal protective equipment worn by first responders is sufficient to block all types of radiation exposure. (F)	95.6 (414)	96.0 (267)	94.8 (147)	NS
All types of radiation can only be stopped by dense materials, such as lead or concrete. (F)	80.8 (350)	83.8 (233)	75.5 (117)	**< .05**
Doubling the distance from a radiation source will reduce the exposure by half. (F)	34.6 (150)	32.4 (90)	38.7 (60)	NS
First responders need to wear a self-contained breathing apparatus when responding to a radiation event because lungs are the most sensitive organs to radiation exposure. (F)	30.3 (131)	30.6 (85)	29.7 (46)	NS
Radiation Exposure Effects Questions				
Exposure to high doses of radiation over a short period of time can result in acute radiation syndrome. (T)	92.8 (402)	93.5 (260)	91.6 (142)	NS
The earliest symptoms of significant radiation exposure include nausea, vomiting, and headache. (T)	91.2 (395)	93.2 (259)	87.7 (136)	NS
Inhalation & ingestion of alpha particles can be more dangerous than external contamination. (T)	83.4 (361)	84.5 (235)	81.3 (126)	NS
Symptoms occur within minutes after the alpha and gamma radiation exposure. (F)	58.0 (251)	59.7 (166)	54.8 (85)	NS
The biggest threat at the site of a radiological dispersal device detonation is from the explosion rather than the radioactive material. (T)	27.7 (120)	26.6 (74)	29.7 (46)	NS
Decontamination Questions				
Decontamination of victims with radioactive contamination should take priority over life-saving measures. (F)	56.6 (245)	62.6 (174)	45.8 (71)	**= .001**
Removal of clothing eliminates most radiation contamination. (T)	48.7 (211)	51.1 (142)	44.5 (69)	NS
All equipment used for radiation decontamination must be discarded after use. (F)	39.5 (171)	43.9 (122)	31.6 (49)	**= .01**
People who have been exposed to radiation must be decontaminated to prevent exposure to others. (F)	13.2 (57)	11.9 (33)	15.5 (24)	NS
Full-body patient decontamination is needed after radiation contamination. (F)	10.9 (47)	9.7 (27)	12.9 (20)	NS

Note. (T) = True; (F) = False; EMS = Emergency medical services personnel; NS = Nonsignificant

[a]Determined by the X^2 test.

Table 3. Determinants of First Responders' Knowledge of Radiation Exposure and Safety from Multivariate Linear Regression

	Knowledge Score		
Factor	β	*SE*	p-*Value*
Received ≥4 hours of radiological transportation incident training	.56	.23	**<.05**
Firefighter (vs emergency medical services personnel)	.37	.16	**<.05**
Received any training on improvised nuclear device/detonation	.33	.16	**<.05**

Note. SE = standard error.

Differences in knowledge scores were found by occupation and between respondents' knowledge of the 3 content areas: protective measures, exposure effects, and decontamination. Firefighters had higher overall knowledge scores than EMS participants (8.8 vs 8.3, $t = 2.9$, $p < .001$). Firefighters were significantly more likely than EMS personnel to answer the following questions correctly: dense materials are not needed to prevent exposure to all types of radiation (83.8% vs 75.5%, $X^2 = 4.5$, $p < .05$); decontamination of victims with radioactive contamination should take priority over life-saving measures (62.6% vs 45.8%, $X^2 = 11.6$, $p = .001$); and all equipment used for radiation decontamination must be discarded after use (43.9% vs 31.6%, $X^2 = 6.3$, $p = .01$; Table 2).

Average knowledge scores for the protective measures and exposure effects subscales were 3.4 and 3.5, respectively, which were both significantly higher than the average decontamination subscale knowledge score (1.7; $F = 515$, $p < .001$). Determinants of radiation exposure and prevention knowledge included having received at least 4 hours of training on radiological transportation incidents, being a firefighter, and having received any training on improvised nuclear devices or detonation (Table 3). No other demographic variable, amount or type of training, or attitudinal belief was a predictor of knowledge.

Dirty Bomb Preparedness and Risk Perceptions

Most (82.0%, $n = 355$) reported being able to perform their work duties during a dirty bomb attack, but significantly fewer ($X^2 = 129.1$, $p < .001$) reported knowing how to do so (64.7%, $n = 280$; Table 4). Firefighters were more likely than EMS personnel to report being able to and knowing how to perform their work duties during a dirty bomb attack (Table 4). Approximately a third (37.2%, $n = 161$) would feel safe working after a dirty bomb attack; there was not a significant occupational difference (Table 4).

About half (45.7%, $n = 198$) reported believing that a naturally occurring radiological event is likely to occur in their city in the next 5 years (Table 4). Significantly fewer ($X^2 = 63.5$, $p < .001$) believed that a radiological terrorism attack would occur in their city in the next 5 years (24.5%, $n = 106$; Table 4). Overall, 43.6% ($n = 189$) reported concern about radiation exposures from their routine work duties, with more firefighters than EMS personnel reporting concern (53.6% vs 25.8%. $X^2 = 31.2$, $p < .001$; Table 4).

Radiological Event Training, Exercise Participation

Participants were asked about the number of hours of training they received on 5 types of radiological events: radiological dispersion device (ie, dirty bomb), radiological exposure device, radiological transportation incident, nuclear reactor incident, and improvised nuclear device detonation. About a third reported that they had not received any training on dirty bombs (33.5%, $n = 145$), radiological exposure devices (32.6%, $n = 141$), or radiological transportation incidents (36.5%, $n = 158$). Half (50.1%, $n = 217$) had not received any training on improvised nuclear devices, and a little more than half (58.7%, $n = 254$) had not received any training on nuclear reactor incidents. About a quarter (23.6%, $n = 102$) had not received any of the 5 types of radiological event training.

The amount of training received for each type of radiological event is outlined by occupation in Table 5. Firefighters received significantly more training than EMS personnel on all types of radiological events except for nuclear reactor incidents (Table 5); this was true even at the agency that employs both firefighters and EMS personnel ($p < .01$ for all comparisons). Participants were significantly more likely to have received training on any radiological exposure device compared to all other types of radiological event training ($p < .001$ for all comparisons).

Participants were asked whether they had participated in a disaster exercise involving a radiological disaster/dirty bomb, earthquake or natural disaster, or influenza pandemic during the past 3 years. About a quarter (27.9%, $n = 121$) had participated in a natural disaster exercise; significantly fewer had participated in a pandemic exercise (14.3%, $n = 62$) or radiological event exercise (13.9%, $n = 60$) ($p < .001$ for both comparisons). Emergency medical services personnel were more likely than firefighters to have participated in a natural disaster exercise (41.9% vs 20.1%, $X^2 = 23.5$, $p < .001$) or pandemic exercise (23.9% vs

Table 4. Firefighters' Versus Emergency Medical Services Personnel's Attitudes and Beliefs Regarding Radiation Exposure Risks and Preparedness to Respond to a Dirty Bomb

	All Respondents N = *433*	*Firefighter vs EMS* N = *433*		*Firefighter vs EMS*
		Firefighter n = *278*	*EMS* n = *155*	
Attitude and Belief Statement	*Strongly Agreed or Agreed* % (n)	*Strongly Agreed or Agreed* % (n)	*Strongly Agreed or Agreed* % (n)	p-*Value*[a]
I would be able to perform my work duties during a dirty bomb attack.	82.0 (355)	85.3 (237)	76.1 (118)	**<.05**
I know how to perform my work duties after a dirty bomb attack.	64.7 (280)	69.4 (193)	56.1 (87)	**<.01**
A naturally occurring radiological event is likely to occur in my city in the next 5 years.	45.7 (198)	43.2 (120)	50.3 (78)	NS
I am concerned about radiation exposure from my work duties.	43.6 (189)	53.6 (149)	25.8 (40)	**<.001**
I would feel safe performing my normal duties during a dirty bomb attack.	37.2 (161)	39.6 (110)	32.9 (51)	NS
A radiological terrorism attack is likely to occur in my city in the next 5 years.	24.5 (106)	23.7 (66)	25.8 (40)	NS

[a]Determined by the X^2 test.
Note. EMS = Emergency medical services personnel; NS = Nonsignificant.

9.0%, $X^2 = 17.9$, $p < .001$); they were equally likely to have participated in a radiological event exercise.

Discussion

This study found that first responders' knowledge of radiation exposure and prevention measures is low. On average, participating first responders answered more than half of the knowledge questions incorrectly. No existing studies were identified that measured first responders' knowledge of radiation exposure, making it impossible to compare these results to prior research. Despite this, some conclusions can be drawn.

Findings from this study indicate that the largest gap in first responders' knowledge relates to patient decontamination procedures for radiological events. Patient decontamination is an essential skill for first responders, because they will be responsible for removing victims from a contaminated scene and decontaminating them before triage and treatment can be performed.[2,3,5,17] First responders need to understand when and how to perform patient decontamination safely to minimize exposure to others and themselves.[2,3,5,17] Patient decontamination may be required after a naturally occurring or man-made radiological event, making this information vital to routine duties as well as a component of terrorism preparedness.

A critical finding from this study is that many first responders have received either no or very little training on radiological events; a quarter had not received any of the 5 types of radiological event training, and many more had received 1 hour or less. This is similar to results of prior studies conducted in the United States. A 2005 study[18] indicated that fewer than 10% of US EMS personnel had received radiological terrorism training from public health officials. Two years later, a 2007 study[8] reported that only about a third of US EMS personnel had received any training on radiological terrorism, though a little more than half had been trained on patient decontamination procedures.

The lack of radiological terrorism training among US first responder personnel reflects training received by other healthcare providers. Emergency department nurses and physicians have reported a lack of training and readiness for radiological terrorism.[4] A national study of US nuclear medicine technologists found that fewer than a third had been trained on radiological terrorism.[19] In contrast, a 2009 study conducted in Canada[10] found that 63% of EMS personnel had received radiological event training. The reason for this difference between the United States and Canada is unclear. One factor that might be influencing the lack of radiological event training is the general low risk perception of such an event happening. Few first responders in this study reported believing that either a naturally occurring or man-made radiological event would

Table 5. Firefighters' and Emergency Medical Services Personnel's Radiological Event Training Received

Type of Radiological Event Training	*No Training* % (n)	*≤1 Hour of Training* % (n)	*2-3 Hours of Training* % (n)	*≥4 Hours of Training* % (n)	p *Value*[a]
Radiological dispersal device/dirty bomb					
Firefighters ($n=278$)	31.3 (87)	27.3 (76)	16.2 (45)	25.2 (70)	**<.01**
EMS ($n=155$)	37.4 (58)	37.4 (58)	16.8 (26)	8.4 (13)	
Radiological exposure device					
Firefighters ($n=278$)	27.3 (76)	32.0 (89)	17.6 (49)	23.0 (64)	**<.001**
EMS ($n=155$)	41.9 (65)	37.4 (58)	14.2 (22)	6.5 (10)	
Radiological transportation incident					
Firefighters ($n=278$)	32.4 (90)	31.3 (87)	16.2 (45)	20.1 (56)	**<.001**
EMS ($n=155$)	43.9 (68)	33.5 (52)	17.4 (27)	5.2 (8)	
Improvised nuclear device/nuclear detonation					
Firefighters ($n=278$)	47.5 (132)	27.0 (75)	11.2 (31)	14.4 (40)	**<.05**
EMS ($n=155$)	54.8 (85)	29.7 (46)	11.6 (18)	3.9 (6)	
Nuclear reactor incident					
Firefighters ($n=278$)	57.9 (161)	24.8 (69)	7.6 (21)	9.7 (27)	NS
EMS ($n=155$)	60.0 (93)	25.2 (39)	11.6 (18)	3.2 (5)	

NS = not significant
[a]Determined by a Mann-Whitney *U* test.

occur in their community in the next 5 years, though the risk perception for a naturally occurring radiological event was much higher than that of a dirty bomb. In addition, only about half of the first responders in this study expressed concern about radiation exposures. These attitudes and beliefs regarding the likelihood of a radiological disaster occurring, or even exposure from routine work duties, may mean that radiological event training is a lower priority than other types of training provided by first responder agencies. A 2018 study reported that only a third of participating first responder agencies had sufficient funding to provide radiological terrorism training;[20] this likely forces agencies to prioritize which staff receive such training or whether it will be provided at all.

An interesting finding from this study is that firefighters had higher knowledge scores and reported receiving more radiological event training than EMS personnel. The reason for these discrepancies is unclear, especially given that 1 of the 2 participating first responder agencies employs both firefighters and EMS personnel and the results were consistent in this subgroup. Perhaps the first responder agency administrators or education coordinators perceive less importance for EMS training on radiological events; the reasons for this should be evaluated in future studies so that intervention studies can be developed to address this gap. Firefighters in this study expressed more concern than EMS personnel about exposure to radiation. This may be due to the increased radiological event training they had received, or there may be other factors influencing these concerns.

Very few first responders in this study reported participation in a disaster exercise involving a radiological scenario during the past 3 years, and they were significantly more likely to have participated in a natural disaster or pandemic exercise. This is likely due to a lack of radiological terrorism exercises available to first responders compared to other types of drills.[21] A previous study with emergency department nurses and physicians found that many hospitals also do not offer radiological terrorism exercises.[4] This is an important gap in radiological event preparedness that needs to be addressed. Disaster exercises play a vital role in testing participants' knowledge and skills in responding to an event and can highlight areas of emergency management plans that need to be improved.[4,7,21] Exercises that involve a radiological scenario are particularly important, because they allow first responders to practice patient decontamination procedures, use of radiation detection equipment, clinical decision making for patients with radiation exposure, and donning and doffing of personal protective equipment.[4,7,21] A 2006 study with EMS personnel involving a radiological terrorism exercise found that half did not correctly identify when patient decontamination was needed and three-quarters entered the hot zone without wearing appropriate personal protective equipment.[21]

Findings from this study indicate that many first responders do not know their job duties during a radiological terrorism attack, and only about a third would feel safe responding to such an event. This illustrates the need for first responder agencies to increase radiological event training opportunities and exercises involving radiological scenarios to better prepare their staff to respond to future events. Radiological event training has been associated with healthcare staff's increased confidence in providing care to radiation victims[8] and with a higher willingness to work during a radiological terrorism event,[9,19,22] making this training essential to community resilience.

Many training programs and/or lists of competencies that should be covered for radiological preparedness have been developed.[2,3,5,10,17,23-25] Many programs emphasize the importance of including a hands-on approach to training, as this has been found to increase first responders' confidence in using radiation detection equipment, performing patient decontamination procedures, selecting and using personal protective equipment correctly, and treating patients with radiation exposure.[2,3,8,21] First responder agencies could partner with public health officials, nuclear medicine technicians, or university personnel to develop radiological event training or exercises, as these groups have been identified as experts in the field.[18,19,25]

For communities near a nuclear power plant, first responder training options also include the Nuclear Regulatory Commission's Radiological Emergency Preparedness Program (REPP for onsite responders) and the Federal Emergency Management Agency's Radiological Emergency Preparedness (REP) program (for off-site responders).[26] The training available through these programs could be incorporated or expanded into other radiological disaster preparedness programs for first responders.

In addition to pre-event training, it will be vital that first responders have access to just-in-time training and information regarding responding to a radiological event.[4,25,27] Smartphone apps, such as Radiation Emergency Medical Management (REMM), which can be used even without internet access should be considered, as they can provide just-in-time response information.[25] A validated training program for REMM has been developed, and both the training and the app are free of charge.[25] First responder agency administrators should consider encouraging their staff to receive this training and use this free app to aid in radiological event preparedness and response.

One of the strengths of this study is that it is the first to examine first responders' training related to multiple types of radiological events (instead of only radiological terrorism), and the first to assess their objective knowledge of radiation exposure instead of just their perceived readiness to respond. Some limitations must also be recognized. This study involved first responders from 2 first responder agencies in a midwestern major metropolitan area and therefore may not be generalizable to other first responders in that region or other parts of the United States. All of the first responders in this study were employed full time in the field. If the sample had included volunteer first responders, the results would likely have indicated even lower

knowledge and less training received. As with all survey research, there may be some recall bias. In addition, the data is self-reported and may involve social desirability bias, though the anonymous nature of the study should limit this.

Conclusion

Findings from this study indicate that many first responders are not receiving training on naturally occurring and man-made radiological events nor participating in exercises that involve a radiological scenario. Subsequently, their knowledge of radiation exposure risk and control measures is quite low. It is vital that first responders receive radiological event training, participate in exercises involving radiological scenarios, and have access to just-in-time information and resources. Such training has been found to be associated with an increased willingness to work during a radiological terrorism event, which will increase a community's resilience. Many free training programs exist; first responder agency administrators should encourage their staff to participate in this training.

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