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Electromagnetic Radiation Knowledge, Risk Awareness, and Shielding Practices of South Korean Occupational Therapists During Videofluoroscopic Swallowing Study: A Survey study

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The videofluoroscopic swallowing study (VFSS) based on electromagnetic radiation is an instrumental test for diagnosing and rehabilitating dysphagia that is performed by many occupational therapists (OTs) in South Korea. This study aimed to investigate current electromagnetic radiation knowledge, risk awareness, and shielding practices of OTs performing VFSS and to identify educational experience on radiation protection. An online survey was conducted from April 2019 to June 2022, and a total of 69 responses were used for analysis. The mean correct score of 'Radiation Knowledge' was 3.24 ± 1.98 (out of 10). Mean scores of 'Risk Awareness' and 'Shielding Practice' were 2.18 ± 0.53 and 3.02 ± 0.74 (out of 5), respectively. Multiple regression analyses revealed that radiation knowledge ($\beta = 0.292$, $p = 0.012$) and risk awareness ($\beta = 0.495$, $p < 0.001$) were significant factors associated with shielding practices. Ninety-five percent of respondents had no radiation-related educational experience, and 83% reported that the reason for not participating was due to a lack of educational opportunities.

Keywords : electromagnetic radiation protection, clinical education, videofluoroscopic swallowing study, X-ray fluoroscopy, occupational therapist survey

1. Introduction

The videofluoroscopic swallowing study (VFSS) based on electromagnetic radiation is an instrumental assessment used to identify normal or abnormal swallowing anatomy and physiology. The VFSS is currently used as the gold standard assay for estimating the swallowing health of patients with dysphagia [1]. Occupational therapists (OTs) provide comprehensive rehabilitation, habilitation, and palliative care to clients with various diagnoses of dysphagia. OTs engage in screening and in-depth clinical assessments. As part of this process, OTs engage in instrumental dysphagia assessments such as the VFSS. Further, OTs work with clients and caregivers to determine mutual goals and optimal outcomes for swallowing skills and in order to provide focused interventions [2]. Globally, VFSS examinations are typically conducted by a team of rehabilitation doctors, radiological technologists, speech-language pathologists (SLPs), and OTs [3, 4]. In accordance with the Act on Medical Service Technologists in South Korea, the scope of work of OTs encompasses rehabilitation treatment for dysphagia as the main activity [5]. A study by Seo et al. [6] reported that 53.4 % of institutions at which OTs work in South Korea employed the VFSS as an instrumental test, and 89.6 % of OTs reported that they participated in VFSS examinations. In VFSS examinations, OTs plan the overall examination process, prepare various examination substances mixed with barium, and communicate with the patient. During the VFSS examination, OTs remain close to the patient to help them with proper positioning and provide them with barium media. This proximity indirectly exposes OTs to

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primary and secondary X-ray radiation, which can ionize human body cells. In the VFSS, electromagnetic radiation dose is typically controlled by an X-ray technician or radiologist. However, it is necessary for OTs to possess basic knowledge about electromagnetic radiation dose and prevention measures to mitigate exposure risks that may affect their own health.

Primary X-rays (primary rays) are a form of electromagnetic radiation emitted by fluoroscopy devices, most of which pass through patient tissue in the field of view (FOV) to reach an image detector and create the resulting image [7]. In this regard, most primary rays are not considered to irradiate the examiner. However, primary rays can convert to secondary X-rays (secondary rays) by colliding with various particles in the patient's body. Secondary ray entry pathways may omnidirectionally differ from those of primary rays via a process termed "scattering" [8]. Scattered secondary rays may thus irradiate OTs proximal to the patient. McLean *et al.* [9] reported that the main cause of workplace radiation exposure is scattered radiation from this process. Moreover, Chan *et al.* [10] reported that VFSS operators located 100 cm from the patient could be irradiated by scattered X-rays. According to Hayers *et al.* [11], it is estimated that VFSS providers perform an average of 780 procedures per year. Compared with the annual natural radiation exposure level of 2-3 mSv, the average dose from a single VFSS procedure is an acceptable level of 0.2 to 1.4 mSv [8,12]. However, the effects of cumulative doses due to repeated VFSS examinations may lead to a stochastic increase in the negative effects of radiation. Stochastic effects include genetic mutations and possible deleterious biological effects of EMR and continuous low-dose radiation exposure, resulting in radiation-induced cancer and fetal malformations [12]. Therefore, shielding strategies such as securing distance from electromagnetic radiation sources and employing personal protective equipment are critical [13-15].

In general, occupational workers are encouraged to follow the radiation protection guidelines established by the International Commission on Radiological Protection (ICRP). The ICRP has proposed guidelines for the protection principles outlined by the Time-Distance-Shielding theory [16]. Limiting examination time, staying as far away from the X-ray source as possible, and equipping facilities with well-maintained shielding devices such as a lead apron and proper collimator are necessary steps to reduce radiation exposure. In addition, equipping personnel with X-ray dosimeters to measure cumulative doses of radiation is critical. In South Korea, a periodic continuing education system (CES), which educates providers on detailed ICRP protection principles, has been legalized for use by several types of radiation workers and plays an essential role in reinforcing radiation remediation steps. Despite efforts to protect workers, OTs, who perform VFSS examinations in South Korea, are generally not subject to periodic radiation-related CES due to incomplete regulations. This incomplete regulation may be due to the small proportion of OTs participating in VFSS examinations. As a result, OTs may have insufficient knowledge and awareness of electromagnetic radiation risks, which can lead to poor protection against occupational radiation. In addition, there is a paucity of studies on radiation exposure among OTs, which has obscured understanding of the relevant implications and dynamics in South Korea. Therefore, this study aimed to investigate current Electromagnetic radiation knowledge, risk awareness, and shielding practices of Korean OTs performing VFSS examinations in hospitals and to identify educational experience on electromagnetic radiation protection.

2. Subjects and Methods

2.1. Survey Design

A cross-sectional online survey was conducted to identify the current status of Korean OTs who perform VFSS examinations in hospitals with regard to Electromagnetic radiation knowledge, Electromagnetic radiation risk awareness, and shielding practices. The survey was divided into five sections: (1) general characteristics of participants (such as gender, age, clinical experience, and place of work), (2) electromagnetic radiation knowledge (i.e., harm of radiation and limits of radiation exposure), (3) electromagnetic radiation risk awareness (i.e., concerns about disease occurrence due to occupational radiation exposure, confirmation of individual exposure dose, health effects of occupational radiation exposure, and information sources), (4) shielding practices (i.e., shielding body parts, securing distance from radiation generating devices, and regular management and inspection of shielding devices and personal exposure dose), and (5) participation in radiation-related education and methods of obtaining information (i.e., experience of participating in education, reasons for not participating, and media source of electromagnetic radiation information). Sections (2) to (4) were constructed based on questions about knowledge and perceptions regarding electromagnetic radiation protection from the survey studies of Jeon [17] and Gang [18]. Two radiologists and one OT working in hospitals reviewed and revised the survey items, and reviewed and modified the questionnaire content accordingly. A pilot assessment for clarity, length, and face validity of the questions was performed by four OTs working at a regional hospital. A web-based survey comprising 26 questions was created using Google Survey Forms (www.google.com/forms). The electromagnetic radiation knowledge section consisted of 2-point scaled questions, whereas the electromagnetic radiation risk awareness and shielding practices sections consisted of 5-point scaled questions.

2.2. Participants

OTs registered with the Society for Dysphagia Rehabilitation were invited to participate in this study by email. A total of 326 participants were invited to participate, and 83 OTs made response for the survey. Among the OTs who received the email, those performing VFSS examinations in hospitals were requested to respond. The online survey was active for 3 years beginning on April 2019 to June 2022. Prior online consent was obtained from the respondents before the survey. Survey completion took approximately 10 minutes. During the survey period, one survey invitation was sent by email to encourage participation. Inclusion criteria were OTs performing VFSS examinations regardless of clinical experience in hospital rehabilitation settings. Exclusion criteria included other professions or OTs not performing VFSS examinations.

2.3. Statistical analyses

Statistical analyses were performed using SPSS 25® software (IBM®, United States). Measurement of internal reliability and exploratory factor analysis were conducted to evaluate the appropriateness of the items of risk awareness and shielding practices. The Direct Oblimin method was used for factor rotation, and Cronbach's alpha was calculated for internal reliability. Frequency analysis and descriptive statistical analysis were conducted for the general information of the respondents and survey items. Electromagnetic radiation knowledge scores were calculated for 10 questions whereby one correct answer was given a score of 1, and the scores were averaged. Electromagnetic radiation awareness (6 questions) and shielding practices (7 questions) were rated using a 5-point Likert scale. Linear associations between electromagnetic radiation knowledge, risk awareness, and shielding practice scores were assessed using Pearson's correlation analysis. Multiple regression analyses were used to identify factors related to shielding practices.

Table 1. Demographics of OTs performing VFSS examinations in hospitals participating in the survey (n=69).

Characteristics	Categories	n (%)
Gender	Female	29 (42.0)
	Male	40 (58.0)
Age	20-29	24 (34.8)
	30-39	36 (52.2)
	>40	9 (13.0)
Education	Associate's	12 (17.4)
	Bachelor's	34 (49.3)
	Master's & higher	23 (33.3)
Clinical experience	< 3 years	6 (8.7)
	3-5 years	24 (34.8)
	5-8 years	19 (27.5)
	> 8 years	20 (29.0)
Place of work	Hospital	12 (17.4)
	General Hospital	22 (31.9)
	University Hospital	35 (50.7)

3. Results

3.1. Demographics of survey population

In total, 14 survey results with incomplete responses were excluded, and a total of 69 responses were analyzed. General characteristics of the participants are presented in Table 1. More than 50 % of participants reported an age of 30-39 years (52.2 %). Among participants, clinical experience of 3-5 years was the most common (34.8 %), and bachelor's degree (49.3 %) was the highest level of

Table 2. Internal consistency and exploratory factor analysis for survey items of electromagnetic radiation risk awareness and shielding practices.

Variable	Items (Number of items)	Cronbach α	KMO	Bartlett' Test of Sphericity	
				Chi-Square	df(p)
Radiation risk awareness	Exposure awareness (3)	0.83	0.69	152.578	15(0.000)
	Safety awareness (3)	0.74			
Shielding practice	Protection practice (4)	0.88	0.70	243.010	21(0.000)
	Shielding maintenance (3)	0.78			

KMO: Kaiser-Meyer-Olkin

education. Most of the respondents worked at university hospitals (50.7 %) and general hospitals (31.9 %).

3.2. Analysis of survey items

Internal consistency and exploratory factor analyses were performed on the items of electromagnetic radiation risk awareness and shielding practices (electromagnetic radiation knowledge was excluded as it was based on 2-point scaled questions). Analysis of the internal consistency of survey items revealed that the Cronbach α of electromagnetic radiation risk awareness items was 0.74-0.83, and that of shielding practices was 0.78-0.88. Exploratory factor analysis revealed KMO values of 0.69 and 0.70, respectively. The significance level was $p < 0.05$ in the Bartlett test; thus, the data were suitable for factor analysis (Table 2).

3.3. Electromagnetic radiation knowledge

Table 3 presents the results of radiation knowledge scores. This section was conducted in a quiz format. In total, 36 (52.2%) and 11 (16.2%) respondents answered correctly for all basic questions and all advanced questions, respectively. The mean total score for radiation knowledge was 3.24 ± 1.98 (out of 10). Questions 3 ("Cancer and mutations may stochastically occur by radiation exposure") and 4 ("External radiation exposure

Table 3. Electromagnetic radiation knowledge by survey respondents (*n*=69). The survey items were rated on 2-point scale (yes vs. no).

	Questions	Correct Answer		
		Correct (%)	Total Correct (%)	M±SD
Basic questions	1. Ionizing radiation could injury human body	31 (44.9)	36 (52.2)	3.24±1.98
	2. Every type of radiation is harmful for human	27 (39.1)		
	3. Cancer and mutation could stochastically occur by radiation exposure	44 (63.8)		
	4. External radiation exposure could injury human body	50 (72.5)		
	5. Thyroid gland and breast is the organ does not receive harmful effect from radiation	28 (40.6)		
Advanced questions	6. Exposure dose is inverse proportional to the distance between X-ray source and object (patient or operator)	18 (26.1)	11 (16.22)	
	7. Exposure dose is proportional to exposure time of X-ray source	3 (18.8)		
	8. Scattering X-ray could reach to area besides the field of view	14 (20.3)		
	9. In diagnostic process, patient dose is limited in point of law	6 (8.7)		
	10. Natural radiation is excluded of Shielding object	5 (7.2)		

Table 4. Radiation risk awareness by survey respondents (*n*=69). The top 2 indicates strongly agree and agree, and the bottom 2 indicates disagree and strongly disagree.

Questions	5(Strongly agree)	4	3	2	1(Strongly disagree)	M±SD
	Top 2			Bottom 2		
1. I consider radiation exposure received during VFSS exam could harmful to human body	11.6%	30.4%	31.9%	23.2%	2.9%	2.18±0.53
	42.0%			26.1%		
2. I concern actual disease induced from radiation exposure during VFSS exam	5.8%	21.7%	24.6%	46.4%	1.4%	
	27.5%			47.8%		
3. I think the radiation exposure received during VFSS exam is actually affecting my health	0%	1.4%	10.1%	55.1%	33.3%	
	1.4%			88.4%		
4. I take a periodic health check relevant with radiation exposure	1.4%	2.9%	8.7%	40.6%	46.4%	
	4.3%			87%		
5. I check and maintain a personal dosimeter quarterly	1.4%	0%	1.4%	36.2%	60.9%	
	1.4%			97.1%		
6. My work place provides an enough information relevant with radiation exposure	1.4%	1.4%	8.7%	72.5%	15.9%	
	2.8%			88.4%		

may injure the human body") demonstrated higher correct response rates of 63.8 % and 72.5%, respectively. The remaining eight questions had less than 50 % correct response rates.

3.4. Electromagnetic radiation risk awareness

The mean score of electromagnetic radiation risk awareness was 2.18 ± 0.53. Respondents answered more often in the top-2 (42 %) than in the bottom-2 (26.1 %) for "electromagnetic radiation (x-ray) exposure during VFSS exam is harmful to the human body". However, respondents answered more often in the bottom-2 than in the top-2 for questions of disease occurrence and health effects due to radiation exposure during VFSS examinations and questions related to the workplace environment such as dosimeter checks, periodic health checks, and provision of radiation exposure-related information (Table 4).

3.5. Current shielding practices

Table 5 presents the survey results on current shielding practices. Mean shielding practice score was 3.02 ± 0.74. Questions related to shielding practices (questions 1 and 2) were answered in the top-2 less often than in the bottom-2 (42.0% and 43.4%, respectively). Similarly, questions related to personal shielding strategy (questions 3 and 4) were answered more often in the top-2 than in the bottom-2 (44.9% and 39.1%, respectively). However, questions related to exposure dose management (questions 5-7) were answered more often in the bottom-2 than in the top-2 (89.9%, 75.3%, and 71.0%, respectively).

Assessment of the provision of shielding devices and their practical use revealed that lead aprons were most frequently provided (94.2%) and used (91.3%), followed by lead collars (59.4% provided, 40.6% used), lead gloves (10.1% provided, 10.1% used), and lead glasses (11.59% provided, 7.3% used) (Fig. 1).

3.6. Correlations among electromagnetic radiation knowledge, risk awareness, and shielding practices

Electromagnetic radiation knowledge scores exhibited moderate linear correlations with electromagnetic-radiation risk awareness (r = 0.31, p < 0.01) and shielding practice scores (r = 0.46, p < 0.01). Electromagnetic radiation risk awareness scores exhibited a strong linear correlation with shielding practice scores (r = 0.55, p < 0.01) (Table 6).

Table 6. Correlation between radiation knowledge, radiation risk awareness, and shielding practice (n=69).

Variable	Correlation		
	Knowledge	Awareness	Shielding Practice
Knowledge	1		
Awareness	0.31**	1	
Shielding Practice	0.46**	0.55**	1

**correlation analysis resulted significant Pearson's coefficient (r) between two variables (p<0.01)

Table 5. Shielding practice by survey respondents (n=69). The top 2 indicates strongly agree and agree, and the bottom 2 indicates disagree and strongly disagree.

Questions	5(Strongly agree)	4	3	2	1(Strongly disagree)	M±SD
	Top 2			Bottom 2		
1. I equip a shielding device on Thyroid gland	11.6%	30.4%	24.7%	30.4%	2.9%	3.02±0.74
	42.0%			33.3%		
2. I equip a shielding device on reproductive organ	10.1%	33.3%	21.8%	29.0%	5.8%	
	43.4%			34.8%		
3. I effort to reduce exposure time during VFSS exam	8.7%	36.2%	30.4%	15.6%	8.7%	
	44.9%			24.3%		
4. I effort to keep far from X-ray source during VFSS exam	11.6%	27.5%	37.7%	14.5%	8.7%	
	39.1%			23.2%		
5. I equip a personal dosimeter during VFSS exam	0%	4.3%	5.8%	23.2%	66.7%	
	4.3%			89.9%		
6. Shielding devices in my work place are regularly checked and maintained	0%	4.3%	20.3%	36.2%	39.1%	
	4.3%			75.3%		
7. Individual exposure dose of radiation workers is regularly managed and checked in my workplace	0%	5.8%	23.2%	36.2%	34.8%	
	5.8%			71.0%		

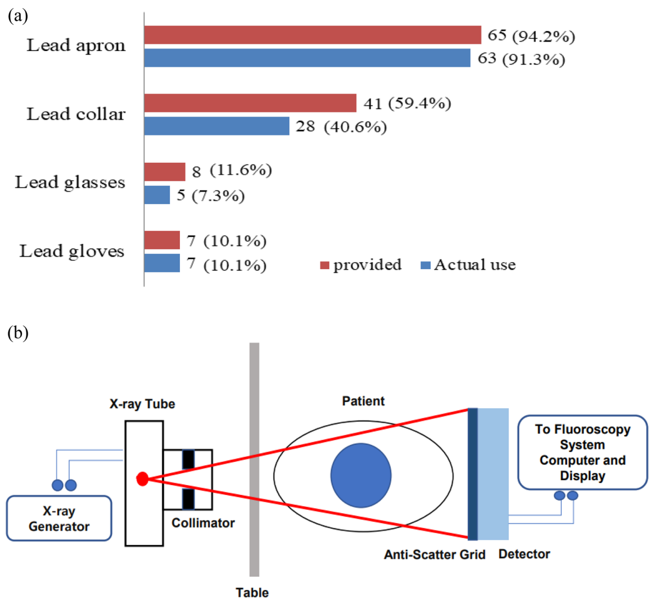

Fig. 1. (Color online) Current shielding practices (n=69) and the main components of VFSS. (a) Provision of shielding devices and their practical use were reported by respondents, (b) Simplified diagram showing the main components of VFSS.

3.7. Factors affecting shielding practices

Multiple linear regression analyses were used to investigate factors affecting shielding practice scores (Table 7). Shielding practice score was set as a dependent variable, and demographic information, electromagnetic radiation knowledge, and risk perception were set as independent variables for analysis. The analysis identified electromagnetic radiation knowledge and risk awareness as factors affecting shielding practices.

3.8. Experience participating in electromagnetic radiation-related education

Only three participants reported that they had experience participating in electromagnetic radiation-related education. With regard to reasons for not participating in education, the survey revealed that 'no educational opportunities' had the highest response rate (83.3%), followed by 'unnecessary' (15.2%), and 'no time' (1.5%) (Table 8).

3.9. Information sources and reliability

Fig. 2 presents the results of a survey on sources from which OTs obtained electromagnetic radiation-related information and sources considered to be most reliable.

Table 8. The reason for not participating in radiation protection education (n=66). The survey item was reported by respondents who had no experience participating in radiation protection education.

Reason	n (%)
No educational opportunities	55 (83.3%)
Unnecessary	10 (15.2%)
No time	1 (1.5%)

Table 7. Factors affecting the shielding practice (n=69).

Dependent Variable	Source		Unstandardized Coefficients		Standardized Coefficients	t	p	R^2
			Beta	SE	β			
Radiation Protection	Knowledge		0.932	0.360	0.292	2.485	0.012	0.478
	Awareness		0.596	0.155	0.495	3.848	<0.001	
	Gender	Gender dummy1	0.181	0.153	0.142	1.181	0.243	
	Age	Age dummy1	-0.019	0.208	-0.015	-0.09	0.929	
		Age dummy2	0.013	0.303	0.007	0.045	0.965	
	Education	Education dummy1	-0.091	0.216	-0.073	-0.422	0.675	
		Education dummy2	-0.106	0.267	-0.079	-0.396	0.694	
	Clinical experience	Clinical experience dummy1	-0.126	0.351	-0.091	-0.360	0.720	
		Clinical experience dummy2	-0.281	0.324	-0.200	-0.866	0.390	
		Clinical experience dummy3	-0.238	0.278	-0.181	-0.858	0.395	
	Place of work	Place of work dummy1	0.407	0.204	0.302	1.994	0.051	
		Place of work dummy2	0.248	0.195	0.197	1.272	0.209	
	Participating education	Participating education dummy1	-0.023	0.373	-0.007	-0.062	0.951	

*Adjusted R^2=0.354, F=3.869

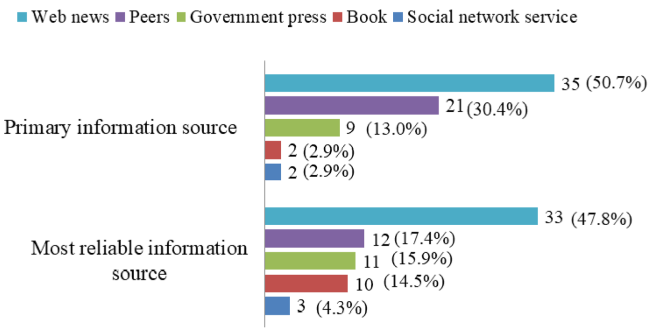

Fig. 2. (Color online) Sources of radiation-related information (n=69). Electromagnetic radiation-related information and sources considered to be most reliable were reported by respondents.

The most common sources of radiation knowledge were ‘web news’ (50.7%), ‘peers’ (30.4%), ‘government press’ (13%), ‘books’ (2.9%), and ‘social network services’ (2.9%). Similarly, the source considered to be most reliable was ‘web news’ (47.8%), followed by ‘peers’ (17.4%), ‘government press’ (15.9%), ‘books’ (14.5%), and ‘social network services’ (4.3%).

4. Discussion

The purpose of this study was to investigate current practices of South Korean OTs performing VFSS examinations in hospitals with regard to electromagnetic radiation knowledge, risk awareness, and shielding practices. Further, we investigated experience participating in radiation protection education amount OTs in South Korea.

4.1. Electromagnetic radiation knowledge and radiation risk awareness

Our survey revealed that OTs performing VFSS examinations only possessed basic electromagnetic radiation knowledge (3.24 ± 1.98 out of 10), and awareness of electromagnetic radiation risk (2.18 ± 0.53 out of 5) was low. Russell *et al.* [19]. reported that SLPs performing VFSS lack radiation knowledge and safety awareness, resulting in an increased possibility of unnecessary radiation exposure. It is consistent with the results of this study. Time, distance, and shielding are three major factors influencing radiation safety. Radiation dose is not inversely proportional to the distance from the radiation source; rather, it is inversely proportional to the square of the distance [20]. In other words, doubling the distance from the electromagnetic radiation source reduces radiation exposure by 1/4 instead of 1/2. Thus, maintaining a greater distance from the X-ray source is a highly effective method for radiation safety. Moreover, radiation exposure accumulated over time. To shorten use time, the intervention skills of the examiner must be improved, and the radiologist must assess the X-ray at the correct location and correct time without image blurring [21]. With regard to the relationship of exposure dose with distance from electromagnetic radiation source and duration of radiation exposure, which are key radiation protection strategies, the percentage of correct answers was 26.1% and 18.8%, respectively. This indicates that OTs have insufficient knowledge of radiation and few opportunities to acquire electromagnetic radiation-related knowledge.

The observation that electromagnetic radiation exposure during VFSS examinations was not considered a significant risk by OTs may be largely underpinned by factors in the workplace environment. In the ‘electromagnetic radiation risk awareness’ section, OTs with low awareness of radiation risk reported that individual exposure dose checks and health check-ups related to radiation contact were not conducted at their current workplace, and workplaces did not provide information or guidance related to radiation exposure. According to Hayes *et al.* [11], the average annual radiation dose for VFSS operators is 1.17 mSv/year, which is 5.85 % of the annual dose limit (20 mSv) for radiation workers. However, without safety measures such as adequate shielding of the inspector and measurement of exposure, the radiation dose may be less than the annual allowable dose, but at least 10 times greater [22]. In this regard, the level of radiation risk is difficult for OTs to determine independently. With the exception of radiology staff, other health professionals such as medical, nursing, and allied health personnel who have access to radiation at a specific time point are not required to be trained or wear radiation-monitoring badges [23]. However, in the context of increasing referrals for VFSS examinations and continuing OT involvement, radiation safety practices should not be overlooked. In contrast to the situation in Korea, the Australian SLP, which is predominantly involved in rehabilitation treatment for dysphagia and VFSS examinations, has raised awareness of the risks of radiation work through legal claims and the Modified Barium Swallow Position Paper, and prioritized the need to improve radiation protection education [24]. In Korea, it is necessary to further educate OTs working in contact with radiation and to increase opportunities to acquire information or education for electromagnetic radiation knowledge and safety management according to task performance.

4.2. Current shielding practices

The mean shielding practice score was 3.02 ± 0.74 (out of 5). The survey responses indicated that implementation of shielding strategies and exposure dose management at the workplace environment level such as wearing a personal dosimeter during VFSS examinations, regular management of shielding devices, and inspection and management of individual exposure dose were rarely performed. Efforts for shielding at the individual level, such as securing a distance from the electromagnetic radiation source, reducing exposure time, and wearing shielding devices for thyroid glands and reproductive organs, showed higher implementation compared to the environmental level. However, only about 40 % of the total respondents responded positively to shielding practices at the individual level, indicating that the implementation at the individual level was also insufficient. In addition, the respondents reported that, with the exception of lead aprons in the workplace, the provision rate for protective equipment such as lead collars, gloves, and glasses, and actual use by OTs were low. The results of this study are in contrast to a previous study on shielding practices of SLPs [25]. (Steele & Murray, 2004). The study reported high usage rates of SLPs for lead aprons, thyroid shields, and lead gloves during feeding, eye protection to limit radiation exposure. Also, 90 % of SLPs responded that they applied dosimetry badges were used over lead aprons or under lead aprons. In hospitals equipped with various types of radiation protection equipment, the protective behavior of workers is higher [26]. According to the radiation protection facility inspection standards of the safety management regulations for diagnostic radiation generators [27], only lead aprons are designated as essential radiation protection equipment. Guidelines for radiation protection following interventional radiological procedures [28] recommend that radiation protection workers wear lead aprons, lead glasses, and appropriate radiation protective equipment such as thyroid guards, because secondary radiation scattered from the patient or wall can affect the eyes, hands, and thyroid gland. Irradiation during the examination is divided into primary radiation that creates a medical image and secondary radiation that scatters to the surroundings regardless of the image. In this regard, secondary radiation is the cause of exposure of individuals in proximity; thus, efforts to maximize shielding are essential [29]. Therefore, it is necessary to legally supplement the mandatory radiation protection devices currently restricted to lead aprons and to increase administrative support for provision of protective devices to encourage use by OTs.

4.3. Factors affecting shielding practices and participation experience in electromagnetic radiation-related education

Electromagnetic radiation knowledge, risk awareness, and shielding practices exhibited a positive linear relationship. Electromagnetic radiation risk awareness and knowledge were the factors most strongly affecting shielding practices ($p < 0.001$ and $p = 0.012$, respectively). This indicates that the shielding practices of OTs during VFSS examinations can be improved through increased electromagnetic radiation knowledge and risk awareness, highlighting the importance of acquiring radiation-related knowledge and practical training. Most survey participants lacked experience in radiation-related education, and 83.3 % of respondents answered that they lacked educational opportunities. In the absence of opportunities for education or acquisition of related knowledge, 80 % of the participants acquired related information predominantly via web searches or peers. This indicates that OTs feel the need to acquire radiation-related information, but currently available methods for acquiring radiation knowledge and safety practices are insufficient. Further, in practice, information from these sources may not be fully reliable. The result of this study is in contrast to the sources of radiation knowledge acquisition reported by Russell *et al.* [19]. They reported that the job training and inservices (57.52 %), medical practicum (17.93 %) completed during academic training, and academic settings (7.34 %) as sources of radiation knowledge acquisition for SLPs.

Warren-Forward *et al.* [24] suggested to SLPs that up-to-date radiation training should be provided to all SLPs in contact with radiation who are responsible for VFSS screening and dysphagia treatment in Australia. They further suggested that it was necessary to introduce radiation safety education at the university level and to provide practical education to supplement theoretical knowledge in the X-ray room. This highlights future directions for domestic OTs performing VFSS examinations. In Korea, formal education or informal training for OTs who contact radiation should be conducted at the stage of preparing for work and the workplace. Radiation-related knowledge in occupational therapy programs including dysphagia courses should be integrated, and opportunities to provide relevant information on safety awareness and shielding practices in workplaces should be expanded.

4.4. Limitations

The small sample size of this survey may not fully represent all domestic OTs participating in VFSS examinations; thus, the results of this study should be generalized with caution. In addition, more than 50 % of the OTs who participated in this survey were university hospital workers, and the difference in the distribution of respondents according to the type of medical institution may have affected the results of this survey.

5. Conclusions

South Korean OTs had low radiation knowledge and radiation risk awareness, which were major factors influencing the low rate of shielding practices. Further, radiation-related education and opportunities for acquisition of related knowledge for OTs in South Korea were limited. To improve electromagnetic radiation knowledge, awareness, and shielding practice, there is a priority to provide relevant education and safety training opportunities for OTs, through which OTs performing VFSS examinations can recognize the importance of radiation protection and use appropriate shielding strategies. In addition, it is necessary to implement management and improvement of shielding practices at the workplace environment level, including the provision of shielding equipment.

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