Journal of
Radiation Protection and Research 2017;42(4):205-211
https://doi.org/10.14407/jrpr.2017.42.4.205

pISSN 2508-1888 | eISSN 2466-2461

Intent to Use a Smartphone Application for Radiation Monitoring in Correlation with Anxiety about Exposure to Radiation, Recognition of Risks, and Attitudes toward the Use of Radiation

Eunkyoung Han[1], Carsten Rott[2], Seung-Woo Hong[2,*]

[1]Department of Mass Communication and Journalism, Sungkyunkwan University, Seoul; [2]Department of Physics, Sungkyunkwan University, Suwon, Korea

Technical Paper

Received March 30, 2017
Revision June 14, 2017
Accepted June 26, 2017

Corresponding author: Seung-Woo Hong

Department of Physics, Sungkyunkwan University, 2066 Seobu-ro, Suwon 16419, Korea
Tel: +82-31-290-7047
Fax: +82-31-290-7055
E-mail: swhong@skku.ac.kr

JRPR

ABSTRACT

Background: Radiation is used in a variety of areas, but it also poses potential risks. Although radiation is often used with great effectiveness in many applications, people perceive potential risks associated with radiation and feel anxious about the possibility of radiation exposure. Various methods of measuring radiation doses have been developed, but there is no way for the general public to measure their doses with ease. Currently, many people use smartphones, which provide information about the location of an individual phone through network connections. If a smartphone application could be developed for measuring radiation dosage, it would be a very effective way to measure individuals' radiation doses. Thus, we conducted a survey study to assess the social acceptance of such a technology by the general public and their intent to use that technology to measure radiation doses, as well as to investigate whether such an intention is correlated with anxiety and attitudes toward the use of radiation.

Materials and Methods: A nationwide online survey was conducted among 355 Koreans who were 20 years old or older.

Results and Discussion: Significant differences were found between the genders in attitudes, perceptions of radiation risk, and fears of exposure to radiation. However, a significant difference according to age was observed only in the intent to use a smartphone dose measurement application. Attitudes towards the use of radiation exerted a negative effect on radiation risk perception and exposure anxiety, whereas attitudes towards the use of radiation, risk perception, and anxiety about exposure were found to have a positive impact on the intent to use a smartphone application for dose measurements.

Conclusion: A survey-based study was conducted to investigate how the general public perceives radiation and to examine the acceptability of a smartphone application as a personal dose monitoring device. If such an application is developed, it could be used not only to monitor an individual's dose, but also to contribute to radiation safety information infrastructure by mapping radiation in different areas, which could be utilized as a useful basis for radiation research.

Keywords: Use of radiation, Risk due to radiation, Anxiety about exposure to radiation, Smartphone application for dose measurement

Introduction

Radiation is widely used in nearly all aspects of our lives, from industry, healthcare, and the development of advanced technology [1]. According to the 2012 Radiation/Radioisotope Utilization Study, the total number of institutions using radiation in Korea is

37,931, with an increase of 2.9% from 2011 (36,852 institutions) [2]. However, radiation has the potential to cause direct cellular damage or indirect damage through the ionization of intracellular molecules, which in turn may cause secondary cellular damage, though the degree of radiation-induced damage depends on the type of radiation and its energy [3]. Radiation is often described as a double-edged sword, with both benefits and risks [4], reflecting the contradictory public attitudes concerning the use of radiation. The general population tends to have negative attitudes towards radiation irrespective of how much they know about radiation [5]. However, in a study on college students' attitudes, Han and Lee [6] reported that attitudes differed depending on whether students had received radiation-related education and on gender. Fear of radiation has increased worldwide after the Fukushima nuclear accident in 2011 [7], leading to global concerns on the effects of its radioactivity extending beyond Japan to its neighboring countries, including as Korea. Moreover, anxiety and weariness regarding nuclear power plants and radioactive pollution have increased. Consequently, researchers have recently investigated the public awareness of nuclear accidents and radioactive pollution [8].

Our natural environment, however, can never be free from radiation. Many elements that make up our environment have unstable isotopes, but continue to decay, emitting energy in the form of alpha, beta, and gamma rays. Environmental radiation is also generated by cosmic rays from outer space to the Earth. In order to measure such environmental radiation, provincial atmospheric radiation measurement facilities and stations have been established nationwide in Korea, and the Nationwide Environmental Radioactivity Survey in Korea is published annually [9]. In addition, the Integrated Environmental Radiation Monitoring Network commissioned by the Korea Institute of Nuclear Safety releases real-time radiation dose rates by region.[1)] Depending on the regional characteristics, different structures are in place for administering and overseeing the measurement of radiation in different regions; moreover, the current technology and resources do not allow accurate measurements of how much radiation individuals are exposed to. Many members of the public now own mobile phones with internet connections, which could be used for detecting radiation and transmitting that information. Thus, in the near future, smartphones could be used as radiation dosimeters, providing an effective means of radiation protection. Recently, a study was conducted in which a smartphone application was designed and implemented to allow users to download radiation-related information [10]. However, they designed and tested a dosimetry application that could provide location-based radioactivity information services by checking the location of its potential users [10].

In view of the fact that a dosimetry application could be developed in the future, we investigated the level of intention to use such an application by its potential users. Although dosimetry applications are currently being developed for smartphones [11, 12], some components of such an application, such as GPS tracking, entail a risk of privacy violations. Thus, there is a need for a preliminary survey to evaluate how receptive people are towards the utilization of such applications. Analyzing the public's intentions to use a dosimetry application also involves analyzing public attitudes towards the use of radiation, perceptions of the risks of radiation, and anxiety regarding radiation exposure. To this end, we conducted an empirical study to evaluate how attitudes towards the use of radiation influence perceived radiation risk and anxiety regarding radiation exposure, and to identify correlations of those variables with the intent to use a dosimetry application.

Materials and Methods

We conducted a quantitative study by using an online questionnaire to analyze public attitudes towards radiation and receptiveness towards the use of a dosimetry application. The online questionnaire was answered by a total of 355 respondents who were 20 years old or older from April 23 to 30, 2016, in Korea.

The items of the questionnaire included the following: two items on demographic characteristics, gender, and age (Ta-

Table 1. Distribution of Samples across Gender and Age Groups

Variable		N=355	%
Gender	Male	176	49.6
	Female	179	50.4
Age	20-29	83	23.4
	30-39	90	25.4
	40-49	96	27.0
	50+	86	24.2

1) http://iernet.kins.re.kr/.

https://doi.org/10.14407/jrpr.2017.42.4.205

ble 1); ten items on attitudes towards the use of radiation (AUR) and nuclear power plants [5] (Table 2); five items on the perception of radiation risks (perceived RR) [6] (Table 3); four items on anxiety about exposure to radiation (AER) [13] (Table 4); and four items on the intent to use a dosimetry application [14] (Table 5). All items were measured on a 7-point Likert scale (where 1 = *strongly disagree*; 4 = *neutral*; and 7 = *strongly agree*).

The values of Cronbach's α were 0.736 for AUR, 0.838 for perceived RR, 0.903 for AER, and 0.928 for UI, which confirm the internal consistency. The collected data were analyzed by using the statistical programs SPSS 22.0 (IBM Corp., Armonk, NY) and AMOS 22.0.

Results and Discussion

1. Demographic characteristics of the respondents

Of the 355 respondents, 176 were male (49.6%) and 179 were female (50.4%). The age distribution was relatively homogeneous: 23.4% of respondents were aged 20-29 years; 25.4%, 30-39 years; 27%, 40-49 years; and 24.2%, 50 years or over (Table 1).

2. Attitudes towards the use of radiation (AUR)

The responses concerning the items on AUR are summarized in Table 2. In terms of the 7-point Likert scale, the item *I would agree to the construction of a general hospital or a*

Table 2. Attitudes on the Use of Radiation (AUR)

Item	Mean ± SD
Q20. I'm against the additional construction of nuclear power plants in Korea.	4.82 ± 1.38
Q21. I'm against the construction of nuclear waste disposal facilities in Korea.	4.78 ± 1.44
Q22. I don't want to have a radiology imaging test for a medical diagnose.	3.53 ± 1.38
Q23. I don't want to receive any radiations for medical treatment.	3.29 ± 1.38
Q24. I'm against the installation of an X-ray security inspection stand at the airport.	4.09 ± 1.45
Q25. I'll agree upon the construction of a nuclear power plant in my region.	3.07 ± 1.67
Q26. I'll agree upon the construction of nuclear waste disposal facilities in my region.	2.84 ± 1.68
Q27. I'll agree upon the construction of a general hospital or a university hospital in my region.	4.85 ± 1.29
Q28. I'm against the use of radiations for nondestructive inspection.	3.59 ± 1.40
Q29. I'm against the use of radiations on food.	4.15 ± 1.62

Table 3. Radiation Risks (RR)

Item	Mean ± SD
Q30. Radiation may pose critical damage to our health, regardless of its quantity.	5.01 ± 1.20
Q31. Radiation may cause critical damage to our environment, regardless of its quantity.	5.13 ± 1.22
Q32. Regardless of its quantity, radiation may cause negative effects in the future, though it may look OK at present.	5.21 ± 1.27
Q33. Radiation is harmful, regardless of its quantity.	5.13 ± 1.25
Q34. Risk due to radiation may vary depending on how it is controlled and managed.	5.13 ± 1.27

Table 4. Anxiety about Exposure to Radiation (AER)

Item	Mean ± SD
Q35. I feel anxiety about a possible high exposure to radiations.	5.06 ± 1.19
Q36. I feel anxiety about a possible exposure to radiations.	4.35 ± 1.37
Q37. I feel anxiety about possible genetic influence due to the exposure to radiations.	4.47 ± 1.46
Q38. I feel anxiety about possible development of cancer due to the exposure to radiations.	4.59 ± 1.37

Table 5.Intention of Using a Dosimetry Application (UI)

Item	Mean ± SD
Q66. I am willing to use a Dosimetry Application.	5.10 ± 1.02
Q67. I will speak positively to others about a Dosimetry Application.	5.12 ± 0.94
Q68. I will recommend the use of a Dosimetry Application to others.	5.01 ± 1.03
Q69. I intend to continuously use a Dosimetry Application.	4.97 ± 1.03

university hospital in my region showed the highest score among respondents (4.85 ± 1.29; mean ± standard deviation). We observed that the respondents agreed to the other items in the following order, from highest to lowest agreement: *I'm against the construction of additional nuclear power plants in Korea* (4.82 ± 1.38); *I'm against the construction of nuclear waste disposal facilities in Korea* (4.78 ± 1.44); *I'm against irradiated food* (4.15 ± 1.62); *I'm against the installation of X-ray security inspection stands for airport security inspections* (4.09 ± 1.45); *I'm against the use of radiation for nondestructive inspections* (3.59 ± 1.40); *I don't want to receive radiology imaging tests for a medical diagnosis* (3.53 ± 1.38); *I don't want to receive any radiation for medical treatment* (3.29 ± 1.38); *I would agree to the construction of a nuclear power plant in my region* (3.07 ± 1.67); and *I would agree to the construction of a nuclear waste disposal facility in my region* (2.84 ± 1.68). The responses to the questionnaire showed a generally negative attitude among respondents with respect to the use of radiation. Exceptions were when the use of radiation, such as in the diagnosis of disease or in radioactive treatment, involved issues relating to one's health; in such cases, the use of radiation was positively looked upon by respondents. Using radiation in nondestructive inspections was received relatively positively, and more or less neutral attitudes were expressed regarding the use of radiation in X-ray security inspection stands at airports. Interestingly, we observed a statistically significant gender disparity in the respondents' responses to the items on AUR, with male respondents showing higher scores than female respondents (4.05 vs. 3.66; Table 6).

3. Public perception of the risks of radiation (RR)

Concerning the perceived RR, the respondents agreed most strongly with the item *Regardless of its quantity, radiation may cause negative effects in the future, though it may look OK at the present* (5.21 ± 1.27; mean ± SD). In the order of highest to lowest agreement, this item was followed by *Risk due to radiation may vary depending on how it is controlled and managed* (5.13 ± 1.27); *Radiation is harmful, regardless of its quantity* (5.13 ± 1.25); *Radiation may cause critical damage to our environment, regardless of its quantity* (5.13 ± 1.22); and *Radiation may pose critical damage to our health, regardless of its quantity* (5.01 ± 1.20). Our findings show that despite its widespread use in virtually all fields, radiation was perceived as an acute risk by respondents (Table 3).

4. Anxiety over exposure to radiation (AER)

The AER item with the highest score among the respondents was *I feel anxious about the possibility of being exposed to a high dosage of radiation* (5.06 ± 1.19; mean ± standard deviation). This item was followed by *I feel anxious about the possibility of contracting cancer triggered by radiation exposure* (4.59 ± 1.37); *I feel anxious about the possibility of radiation-induced genetic abnormalities* (4.47 ± 1.46); and *I feel anxious about the possibility of being exposed to radiation* (4.35 ± 1.37). The responses to the questionnaire illustrate that respondents exhibited anxiety over possible exposure to radiation exposure, and especially to high-dose exposure. Additionally, a gender disparity in AER was observed, with female respondents showing more anxiety than male respondents (4.76 vs. 4.48; Table 4).

5. Intent to use a dosimetry application (UI)

The widespread ownership of smartphones means that the utilization of a mobile radiation monitoring system in the form of a dosimetry application may allow individuals to conveniently monitor their radiation dosage. With such applications under development [13], we investigated the receptiveness of the general population towards such dosimetry applications (Table 5). In the order of highest to lowest agreement, we found the following scores of UI-related items: *I will speak positively to others about using dosimetry applications* (5.12 ± 0.94); *I am willing to use a dosimetry application*

Table 6. Differences in Variables by Gender

Variable	Mean		SD		t	p
	Male (n = 176)	Female (n = 179)	Male (n = 176)	Female (n = 179)		
AUR	4.05	3.66	0.86	0.70	4.700	0.000***
RR	5.02	5.22	0.94	0.99	-1.962	0.051
AER	4.48	4.76	1.25	1.11	-2.238	0.026*
UI	4.99	5.11	0.95	0.87	0.353	0.237

*p < 0.05; **p < 0.01; ***p < 0.001.
AUR, attitudes towards the use of radiation; RR, radiation risk; AER, attitudes about exposure to radiation; UI, intent to use.

Table 7. Differences in Variables by Age

Variable	Age	Mean	SD	F/p	Scheffe test
UI	20-29 (a)	4.91	0.89	5.448/0.001	d > a, d > b
	30-39 (b)	4.85	0.93		
	40-49 (c)	5.11	0.88		
	50- (d)	5.34	0.88		

UI, intent to use.

https://doi.org/10.14407/jrpr.2017.42.4.205

(5.10 ± 1.02); *I will recommend dosimetry applications to others* (5.01 ± 1.03); and *I intend to use dosimetry applications on a long-term basis* (4.97 ± 1.03). We observed that the respondents of our survey in general favored the development of dosimetry applications and also showed an intent to recommend them to others. Although UI did not show a gender-specific difference (Table 6), it showed a statistically significant age-dependent difference (F = 5.448, p = 0.001; Table 7), which was further assessed using a post-hoc Scheffe analysis. The analysis showed that the UI scores between 20- to 29-year-olds and over-50-year-olds and between 30- to 39-year-olds and over-50-year-olds significantly differed. Additionally, we found that respondents aged over 50 years generally had a greater intent to utilize a dosimetry application.

6. Correlations between UI and AUR, perceived RR, and AER

To assess the correlations among variables, we employed structural equation modeling. We conducted confirmatory factor analysis for the items in each category, the results of which verified their suitability (Table 8). However, because the analysis illustrated inappropriate structural modeling, the model was modified, as shown in Figure 1, by using a modification index. The modified model depicts the new relationships between the variables. Indices concerning the adapted model were found to be all within the appropriate

Table 8. The Model Fit of Variables

	CMIN/*p*	CMIN/DF	RMR	GFI	AGFI	CFI	NFI	IFI	RMSEA
AUR	41.373/0.000	2.955	0.063	0.968	0.936	0.967	0.951	0.967	0.074
RR	7.163/0.128	1.790	0.024	0.992	0.970	0.996	0.994	0.994	0.047
AER	1.236/0.539	0.618	0.012	0.998	0.991	1.000	0.999	1.000	0.000
UI	0.960/0.327	0.960	0.004	0.999	0.987	1.000	0.999	1.000	0.000

AUR, attitudes towards the use of radiation; RR, radiation risk; AER, attitudes about exposure to radiation; UI, intent to use; DF, degrees of freedom; RMR, root mean square residual; GFI, goodness of fit index; AGFI, adjusted goodness of fit index; CFI, comparative fit index; NFI, normed fit index; IFI, incremental fit index; RMSEA, root mean square index of approximation.

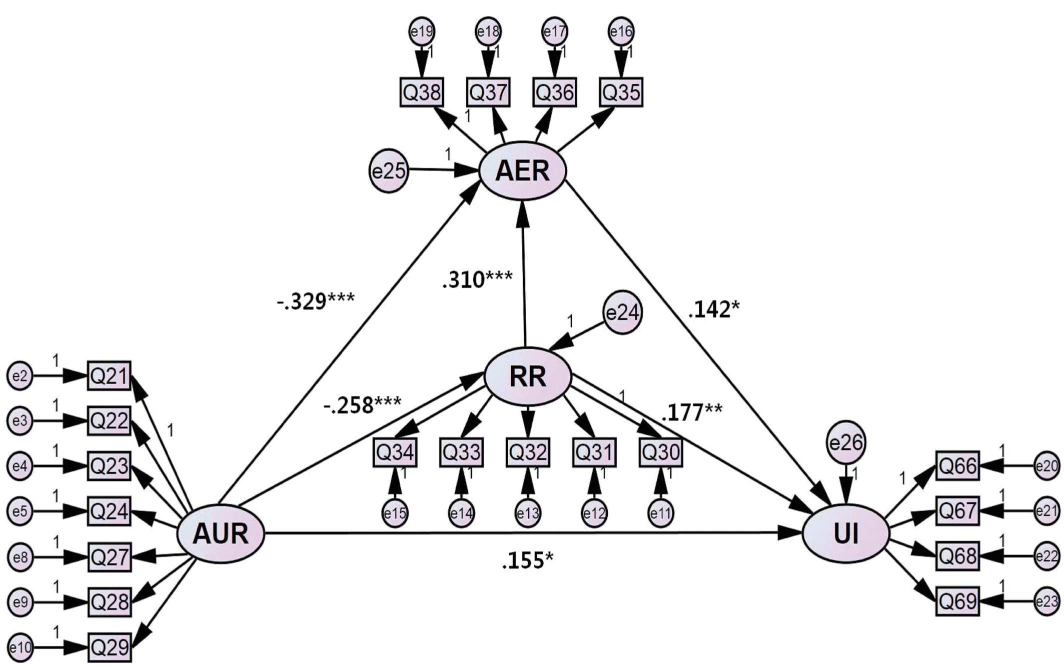

Fig. 1. Schematic diagram of the modified model. The items Q21-Q29 of the questionnaire for AUR are as given in Table 2. The items Q30-Q34 for RR are as in Table 4. Q35-Q38 for AER as in Table 5. Q66-Q69 for UI as in Table 6. The items Q20, Q25 and Q26 are removed from the original model through the modification indexes (M. I.) being * < 0.01, ** < 0.05, *** < 0.001. The numbers on the arrows denote the standard regression weight (r) as given in Table 10. AUR, attitudes towards the use of radiation; RR, radiation risk; AER, attitudes about exposure to radiation; UI, intent to use.

Table 9. The Model Fit of the Structural Model and the Modified Model

	CMIN/*p*	CMIN/DF	RMR	GFI	AGFI	CFI	NFI	IFI	RMSEA
Structural model	531.341/0.000	2.460	0.183	0.882	0.849	0.941	0.905	0.941	0.064
Modified model	292.788/0.000	1.841	0.060	0.925	0.970	0.901	0.938	0.971	0.049

AUR, attitudes towards the use of radiation; RR, radiation risk; AER, attitudes about exposure to radiation; UI, intent to use; DF, degrees of freedom; RMR, root mean square residual; GFI, goodness of fit index; AGFI, adjusted goodness of fit index; CFI, comparative fit index; NFI, normed fit index; IFI, incremental fit index; RMSEA, root mean square index of approximation.

Table 10. The Regression Weight of Study Model

Path	Regression weight (r)	S.E.	C.R.	*p*
RR<---AUR	-0.439	0.097	-4.5131	***
AER<---AUR	-0.658	0.129	-5.1159	***
AER<---RR	0.365	0.062	5.8648	***
UI<---AUR	0.213	0.089	2.3793	0.017*
UI<---RR	0.144	0.049	2.9228	0.004**
UI<---AER	0.097	0.045	2.1891	0.029*

$^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$.
AUR, attitudes towards the use of radiation; RR, radiation risk; AER, attitudes about exposure to radiation; UI, intent to use; S.E., standard error.

range: The ratio of the chi-square value to its degrees of freedom (531.341/216) was 1.841, the root mean square residual (RMR) was 0.060, the goodness of fit index (GFI) was 0.925, the adjusted goodness of fit index (AGFI) was 0.970, the comparative fit index (CFI) was 0.901, the normed fit index (NFI) was 0.938, the incremental fit index (IFI) was 0.971, and the root mean square index of approximation (RMSEA) was 0.049 (Table 9).

Our analysis of the correlations among the variables, summarized in Table 10, showed that AUR was negatively associated with perceived RR (r = -0.439, $p<0.000$) and AER (r = -0.658, $p<0.000$) and positively with UI (r = 0.213, $p=0.017$). Further, more favorable AUR was associated with lower perceived RR and AER, and with higher UI scores. Conversely, less favorable AUR was associated with higher perceived RR and AER. Perceived RR was positively correlated to AER (r = 0.365, $p<0.000$) and UI (r = 0.144, $p=0.004$); that is, those who perceived RR more acutely tended to be more anxious about being exposed to radiation. Likewise, AER was positively correlated with UI (r = 0.097, $p=0.029$).

We evaluated the potential mediating effect of perceived RR or AER on the association between AUR and UI by using bootstrapping. The perceived RR was found to be a mediating variable in the relationship between AUR and AER (r = -0.080, $p=0.006$) and that AER was a mediating variable in the relationship between RR and UI (r = -0.044, $p=0.029$). For the association between AUR and UI, the mediating effect was both direct and indirect, illustrating a two-way mediating effect of perceived RR and AER (r = -0.104, $p=0.003$). Thus, our findings show that the UI of respondents was not only affected by AUR, but also by perceived RR and AER.

Conclusion

In this study, anticipating that a mobile radiation monitoring system in smartphones could be developed in the near future, we investigated potential users' acceptance and their intentions to use such applications, assessing the demand for dosimetry applications. We evaluated public members' attitudes towards the use of radiation, their perceptions of the risks of radiation, and their anxiety over radiation exposure by conducting an online questionnaire among 355 adults in Korea.

In terms of the use of radiation, we found a generally negative attitude among the general population; in particular, respondents were strongly against the construction of nuclear power plants and of nuclear waste disposal facilities in Korea. However, respondents were positive about health-related applications of radiation, such as the use of radiation for medical treatments and in diagnostic medicine. We observed that the general population acutely perceived the risks of radiation and that the anxiety over radiation exposure for health and safety was high. Moreover, respondents were receptive towards the use of dosimetry applications. Interestingly, we found that attitudes towards radiation use and anxiety about radiation exposure showed a gender disparity: male respondents had more positive attitudes towards radiation use than female respondents, and while both genders exhibited anxiety over radiation exposure, female respondents were more anxious than male respondents. Further, age-dependence in the intent to use a dosimetry application was observed. For instance, respondents aged 50 years old or older had higher intentions to use dosimetry applications than younger respondents. This may be because the members of older generations tend to be more health-conscious than the mem-

 https://doi.org/10.14407/jrpr.2017.42.4.205

bers of younger generations and consider protection against radiation exposure to be an important health precaution. Lastly, when we analyzed the correlations among variables, we found that negative feelings towards the use of radiation were associated with higher anxiety concerning perceived RR. Altogether, it seems that people consider assessing the radiation dosage around them to be a means of protecting themselves from radiation.

On the basis of the results of this study, the following practical implications can be discussed. Previous studies have focused on the demographic characteristics of professional or occupational radiation workers in order to evaluate public awareness of radiation [1, 3, 4, 15, 16]. In contrast, our study is the first to evaluate the attitudes of the general population concerning radiation and the intent to use a smartphone dosimetry application. Radiation is extensively used in many fields because it is very useful. Nevertheless, the populace tends to exhibit a negative attitude towards the use of radiation and to acutely perceive the risks associated with radiation. In spite of a population-wide study design, limitation of this study is that the level of radiation/radioactivity-related knowledge of the general population was not taken into account. In the future, it may be useful if studies evaluate how the perceived usefulness of radiation can change attitudes towards its use. The results of this study indicate a public interest in dosimetry applications and a widespread intent to use them, suggesting a clear demand for such applications. Dosimetric information from smartphone-based radiation monitoring systems can even be transferred to an online database. Accumulated dosimetric information can be utilized to boost public awareness of radiation, creating a healthier and safer everyday environment. In addition, national dosimetry mapping could be conducted by combining GPS data and big data from dosimetry applications. The significance of this study lies in the possibility of establishing well-developed infrastructure and radiation-protective measures, and developing an information system contingency plan so that radiation exposure can be minimized. We hope that the findings of this study will be used as a valuable resource for future radiation studies.

Acknowledgements

The paper was supported by Sungkyun Research Fund, Sungkyunkwan University, 2015 (2015-1655-000).

References

1. Han EO, Kwon DM. Analysis of the trend of knowledge, attitude and behavior related to radiation safety management: focused on radiation workers at medical institutions. J. Radiol. Sci. Technol. 2007;30(4):321-327.
2. Korea Association for Radiation Application. Survey on the Status of Radiation/RI Utilization in 2012. MSIP 2013M2B5A1033138. 2013:3.
3. Kim JH, Ko SJ, Kang SS, Choi SY, Kim CS. Analysis of radiation/radioactivity-related knowledge, perception and behavior of radiological technologists. J. Radiol. Sci. Technol. 2007;34(2):123-129.
4. Seoung YH, Kim SS. Structural relationship for recognition of radiation risks on management and benefits of the university students. J. Digital Convergence. 2014;12(2):431-437.
5. Kim JH, Kim CS, Lim CS. Analysis of the risk perception of nuclear power plant and radiation. J. Korea Academia-Industrial cooperation Society. 2012;13(8):3570-3577.
6. Han EO, Lee JI. Attitudes on the use of radiations in some college students. J. Radiat. Prot. Res. 2006;31(4):219-235.
7. Park BJ. Analysis of public perception on radiation: with one year after Fukushima nuclear accident. J. Radiat. Prot. Res. 2012; 37(1):1-9.
8. Ha JC, Song Y. An investigation of awareness on the Fukushima nuclear accident and radioactive contamination, J. Radiat. Prot. Res. 2016;41(1):7-14.
9. Korea Institute of Nuclear Safety. Environmental radioactivity survey in Korea, 2014. KINS/ER-028, Vol. 46. 2014:1.
10. Kim KS, Lee KW. Design and implementation of a smart phone app for location-based services on environment sensor and radioactive information. J. Korean Assoc. Geographic Inf. Stud. 2011;14(4):161-171.
11. Ishigaki Y, Matsumoto Y, Ichimiya R, Tanaka K. Development of mobile radiation monitoring system utilizing smartphone and its field tests in Fukushima: IEEE Sens. J. 2013;13(10):3520-3526.
12. Whiteson D, Mulhearn M, Shimmin C, Cranmer K, Brodie K, Burns D. Observing ultra-high energy cosmic rays with smartphones. arXiv preprint. 2014:1410.2895.
13. Kim KW. A study on anxiety of dental hygienists about being exposed to radiation. J. Korean Academy Dent. Hyg. 2012;14(1):1-9.
14. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly. 1989;13(3): 319-340.
15. Jeon YR, Cho PK, Han EO, Jang HC, Ko JK, Kim YM. The knowledge, attitude and behavior on the radiation safety management for dental hygiene major students. J. Radiol. Sci. Technol. 2015; 38(4):411-420.
16. Moon JM, Park ST, Yu JH. Radiological safety perception change after dose measurement of radiology department students. J. Radiat. Prot. Res. 2015;40(3):174-180.