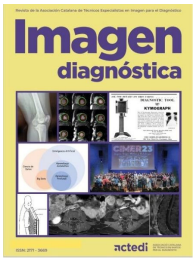

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Awareness of Radiation Safety Among Nurses in Saudi Arabia

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Abstract: Background: Ionizing radiation is widely used as a diagnostic and treatment tool in healthcare. Nurses play a significant role in healthcare environments, accompanying patients during examinations, including exposure to X-ray procedures and are required to adhere to radiation safety protocols. This study aims to assess the knowledge and understanding of ionizing radiation, attitudes and compliance in implementing protective protocols among Saudi nurses in clinical departments. **Method:** A cross-sectional descriptive design was used, involving 261 nurses from different regions of Saudi Arabia. Data were collected through a structured online questionnaire that focused on the participants' exposure to radiation, their knowledge of protective measures and their daily practices, data were analysed using IBM SPSS v26 was mainly used to perform the statistical analysis. The main tools used in the study were descriptive statistics (mean, standard deviation and frequency distribution): these were used to give a descriptive summary about the sample or a segment (sub-group) of it. Chi-square test (under 0.05 level of significance). **Results:** The survey results showed substantial discrepancies in nurses' knowledge of radiation effects, especially among those in non-radiology departments. Among radiology nurses, 62.3% were familiar with the ALARA principle, while only 39.6% of non-radiology nurses demonstrated adequate knowledge. Additionally, 44.2% of the participants had undergone training related to radiation safety. The practice of maintaining a safe distance was at a high level, the consistent use of personal protective equipment was lacking. The results also demonstrate that the training of healthcare professionals must be improved. **Conclusions:** These findings highlight the urgent need to integrate comprehensive radiation safety education into nursing curricula and to implement continuous training programs to address knowledge and practice gaps. Strengthening radiation safety awareness will ultimately enhance patient safety, protect healthcare workers and promote a safer clinical environment.

Key Words: Positron Emission Tomography (PET), Thermoluminescent Dosimeter (TLDs), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Radiation Safety

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INTRODUCTION

The application of ionizing radiation is essential in disease diagnosis and management. Recently, the healthcare field has increased the use of computed tomography and X-ray scans and ionizing radiation-based medical imaging exams [1-3]. However, there is still a lack of research on nurses' level of radiation safety knowledge. The radiology sector in Saudi Arabia has improved significantly, driven by investments in healthcare facilities and cutting-edge imaging technologies. Saudi Arabia has recently adopted advanced modalities such as CT for trauma and stroke assessment and MRI for neurological and musculoskeletal diagnoses [4,5]. While hybrid imaging, such as PET/CT, enhances diagnostic accuracy, interventional radiology provides minimally invasive treatments [6-8]. However, there are still issues, such as healthcare workers' low awareness about radiation safety [9]. The aim of this study is to assess Saudi nurses' knowledge of radiation use and safety procedures across different healthcare settings. By identifying knowledge gaps and assessing current practices, the study seeks to offer insights that can enhance patient care and ensure workplace safety in ionizing radiation settings.

Nurses who work in the radiology department, as well as nurses from other departments who accompany patients, along with other healthcare workers visiting radiology units, are at risk of exposure to ionizing radiation. If not properly controlled, such exposure can lead to significant long-term health risks [3,10,11].

Studies have shown that this exposure is linked to an increased risk of thyroid cancer, leukemia, lung cancer, skin cancer and breast cancer [12,13]. Radiation exposure is also harmful to the eyes, which are at higher risk for cataracts and retinal damage, potentially resulting in permanent vision impairment [14,15]. Regarding fertility, scientific studies show that standing under radiation may affect individuals trying to conceive, leading to issues such as infertility, irregular menstruation, and, in pregnant workers, birth defects or miscarriages. Radiation-induced decline in sperm quality may also cause male infertility [16,17]. In addition, genetic mutations resulting from prolonged radiation exposure have a well-established history of causing disorders not only in the first generation but also in future ones [18,19]. Long-term exposure to interventional procedures has also been linked to cardiovascular diseases, including increased risks of heart disease and hypertension [20-23]. These findings emphasize the importance of implementing strict radiation safety protocols to minimize these risks and to protect the long-term health of healthcare staff by increasing awareness of radiation exposure and protection protocols.

Radiation protection remains a cornerstone of safe clinical practice within radiology, ensuring the well-being of healthcare professionals exposed to ionizing radiation. The foundational principles of radiation safety are grounded in recommendations from the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP), two leading organizations that establish global guidelines. Their primary goal is to minimize radiation exposure to both patients and healthcare workers while maintaining the diagnostic and therapeutic effectiveness of radiological procedures [24]. The concept of radiation protection emerged in the early 20th century following the discovery of X-rays by Wilhelm Roentgen in 1895. As research uncovered the harmful biological effects of prolonged radiation exposure, standardized safety protocols were developed to mitigate associated risks. Three core principles govern radiation protection practices: Justification, optimization and dose limitation. Justification ensures that each exposure is clinically warranted, balancing benefits against risks. Optimization, commonly referred to as ALARA (As Low as Reasonably Achievable), advocates for reducing exposure to the lowest practical levels without compromising diagnostic quality [25]. Dose limitation establishes upper safety thresholds to prevent deterministic effects and reduce the likelihood of stochastic outcomes.

For healthcare providers, particularly those in radiology and interventional specialties, the Personal Protective Equipment (PPE), such as lead aprons (typically 0.25-0.5 mm lead equivalent), thyroid shields and radiation-attenuating lead glasses, serves as a primary physical barrier. Thyroid shields protect the highly sensitive thyroid gland from exposure and can reduce thyroid radiation doses by up to 90% when properly fitted and consistently used. In addition to PPE, radiation safety practices rely on three strategies: shielding, distance and time management [26,27]. Distance is a critical factor; according to the inverse square law, radiation intensity diminishes proportionally to the square of the distance from the source [28]. Minimizing time spent near radiation sources directly reduces cumulative exposure. Technological advancements such as personal dosimeters and dose-monitoring systems have further improved exposure tracking, offering real-time feedback on occupational radiation risks. Radiation monitoring tools, including film badges, thermoluminescent dosimeters (TLDs) and electronic dosimeters, are widely implemented to ensure compliance with exposure limits and to facilitate long-term dose assessment [29]. Dosimetry enables institutions to align practices with national and international safety benchmarks while providing accountability for both staff and administrators. Nevertheless, improper operation of imaging equipment or failure to follow protective protocols can pose serious risks. In X-ray procedures, poor exposure adjustment can subject patients to unnecessarily high doses, increasing the risk of radiation burns and potential genetic mutations. Similarly, failure to wear protective gear, particularly among nurses and ancillary staff, has been associated with increased risks of cataracts, fertility issues and other long-term health consequences [3]. In interventional radiology, lack of shielding, insufficient PPE use and prolonged exposure to scatter radiation in cardiac catheterization labs have been associated with multiple adverse health effects among interventional healthcare workers, raising the risk of developing radiation-induced cardiovascular conditions [30,31]. Equally alarming is the limited awareness of emergency protocols in the event of radiation-related incidents, which can delay response and exacerbate harm [32,33].

Despite the indispensable role of medical imaging in modern healthcare, improper management of radiation exposure poses significant risks to both patients and healthcare personnel. Nurses, who often accompany patients during radiological procedures, must therefore possess a clear understanding of radiation hazards and protective strategies. Studies continue to show critical gaps in radiation safety awareness among nursing staff, largely due to the absence of mandatory training and inadequate integration of safety concepts into nursing curricula. Hands-on workshops and simulation-based training have proven effective in enhancing both theoretical knowledge and practical application [34]. Institutional culture also plays a pivotal role. Facilities that foster a strong safety culture through leadership support, continuous education and non-punitive incident reporting mechanisms achieve better compliance and improved outcomes. Despite growing research in this area, most studies focus on radiographers and radiologists, leaving a significant gap in understanding

the behaviors and challenges faced by frontline nursing staff. This study aims to evaluate the level of knowledge of radiation protection among Saudi nurses, regarding radiation use and safety practices and to assess its impact on patient care and workplace safety in clinical imaging settings.

METHODS

Study Design

This study adopted a cross-sectional descriptive design. Data were collected using an online questionnaire administered via web-based Microsoft Forms during the period from January to April 2025. The questionnaire was specifically developed to assess Saudi nurses' knowledge of radiation use and related safety practices across different regions in Saudi Arabia. The questionnaire was reviewed by experts in radiology and nursing to ensure its validity and relevance. All questions were formulated specifically for the purpose of this research.

The questionnaire was structured into four main sections. The first section gathered demographic and professional background information about the participants. The second section assessed their knowledge of radiation safety principles, including whether they had received formal education on radiation protection and their familiarity with essential concepts such as the ALARA principle. The third section explored the participants' daily practices related to the implementation of radiation protection measures. The final section collected participants' suggestions for improving radiation safety awareness among nurses, such as using instructional posters in clinical settings and integrating radiation safety topics into nursing curricula.

Main Objective

To evaluate the level of knowledge of radiation protection among Saudi nurses, regarding radiation use and safety practices and to assess its impact on patient care and workplace safety in clinical imaging settings.

Inclusion and Exclusion Criteria

The participants included male and female Saudi nurses and nursing interns working in government or private hospitals and clinics across five regions in Saudi Arabia. They were selected from various departments such as Radiology, Emergency, Inpatient, Surgery, Pediatrics, Oncology, Orthopedics, NICU, ICU, Dentistry and other departments.

Non-Saudi nurses, undergraduate nursing students, radiologists, radiology technicians, radiology technologists, radiology trainees and other healthcare workers were excluded from the study.

Statistical Analysis

Data were mainly analyzed using IBM SPSS version 26. The main tools used in the study were descriptive statistics (mean, standard deviation and frequency distribution), which provided a descriptive summary of the sample or a subgroup of it. A Chi-square test (at a 0.05 level of significance) was conducted to examine the existence of associations between two categorical variables. The "linear-by-linear association" method was used when both variables were ordinal; otherwise, Pearson's method (default) was applied. In addition, p-values were calculated using the exact method rather than the conventional method to ensure more accurate results.

Significance of the Study

This study provides valuable insights into Saudi nurses' knowledge of radiation use and safety, highlighting areas of strength and identifying knowledge gaps. The findings may contribute to the development of targeted educational programs and help improve professional attitudes in clinical practice. This, in turn, will enhance patient care and promote a safer working environment in healthcare settings.

RESULTS

Sample Characteristics and Demographics

According to Table 1, the sample characteristics may be summarized as follows:

- More than half of the participants (n = 142, 54.6%) are 21-25 years old
- Nearly half of the participants hold a bachelor's degree (n = 117, 45%) and approximately one-third of them (n = 88, 33.8%) are nursing interns
- The most frequent regions (the participants belong to) are the Western (n = 93, 35.8%) and the Central (n = 77, 29.6%)
- Three-quarters of the participants (n = 195) have work experience of not more than 5 years
- Approximately two-thirds (n = 178, 68.5%) of the participants work in governmental hospitals
- Most of the participants are working in departments dealing with radiation (n = 159, 61.2%)
- The most frequent departments (the participants belong to) are Emergency (n = 64, 24.6%) and Radiology (n = 59, 22.7%)
- 55.8% of the participants (n = 145) did not receive formal training on radiation safety, while 44.2% of the participants (n = 115) received formal training (Figure 1) and the majority of them (n = 213, 81.9%) are interested in starting new training or receiving more (if already taken). Actually, the majority of the participants (n = 210, 80.77%) believe that a lack of training makes it difficult to implement radiation safety guidelines

Knowledge

It can be seen from Table 2 that for those who work in departments dealing with radiation, the ideal answer was chosen by most of them (62-89%) in 4 out of 5 questions. There is only one question (namely: Do you know how to respond to incidents involving radiation exposure in the

Table 1: Sample Characteristics and Demographics

Variable	Categories	Frequency (N = 260)	Percentage
Age	21-25	142	54.6
	26-30	50	19.2
	31-40	54	20.8
	>40	14	5.4
Educational level	Nursing intern	88	33.8
	Diploma	31	11.9
	Bachelor	117	45.0
	Higher education	24	9.2
Region	Central	77	29.6
	Northern	21	8.1
	Southern	22	8.5
	Eastern	47	18.1
	Western	93	35.8
Experience	<1	101	38.8
	1-5	94	36.2
	6-10	23	8.8
	>10	42	16.2
Current Workplace Setting	Government hospital	178	68.5
	Private hospital	56	21.5
	Clinical/health center	24	9.2
Working in department dealing with radiation	Yes	159	61.2
	No	101	38.8
Department	Dentistry Department	15	5.8
	Emergency	64	24.6
	ICU	18	6.9
	Inpatient Department	22	8.5
	Other	39	15.0
	Pediatrics Department	16	6.2
	Radiology Department	59	22.7
	Surgery Department	27	10.4
Receipt of formal training in radiation safety	Yes	115	44.2
	No	145	55.8
Interest in receiving additional training	Yes	213	81.9
	No	47	18.1

Table 2: Knowledge of Participants in Radiation Safety

	Answer by Group							
	Working in Dept. Dealing with Radiation				Not Working in Dept. Dealing with Radiation			
	No		Yes		No		Yes	
Question	N	%	N	%	N	%	N	%
Are you aware of the health risks associated with radiation exposure in the workplace?	18	11.30	141	88.70	15	14.90	86	85.10
Do you know the basic principles of radiation safety, such as the ALARA principle (As Low As Reasonably Achievable)?	60	37.70	99	62.30	61	60.40	40	39.60
Are you familiar with the necessary personal protective equipment (PPE) used for radiation protection?	20	12.60	139	87.40	31	30.70	70	69.30
Are you aware of the local regulations and guidelines on radiation safety?	50	31.40	109	68.60	38	37.60	63	62.40
Do you know how to respond to incidents involving radiation exposure in the workplace?	70	44.00	89	56.00	65	64.40	36	35.60
Overall Score	3.63 (SD = 1.45)				2.92 (SD = 1.67)			
	or 72.58 (SD = 28.95) in 100%-scale				or 58.42 (SD = 33.43) in 100%-scale			

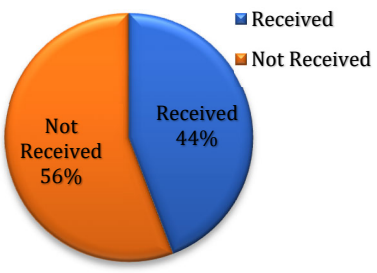

Figure 1: Percentage of Participants Who Received Radiation Safety Training

workplace?), which was just answered by slightly more than half of the participants (56%). Having most of the questions being answered correctly (by most of the participants) is reflected in the average knowledge score (M = 3.63, SD = 1.45), which is nearly 4 (on average, a participant roughly answers 4 out of the 5 questions ideally/correctly). These results indicate a good understanding of radiation protection among participants. On the other hand, for those not working in departments dealing with radiation, the ideal answer was chosen by most of them (62-85%) in 3 out of 5 questions, namely: Are you aware of the health risks associated with

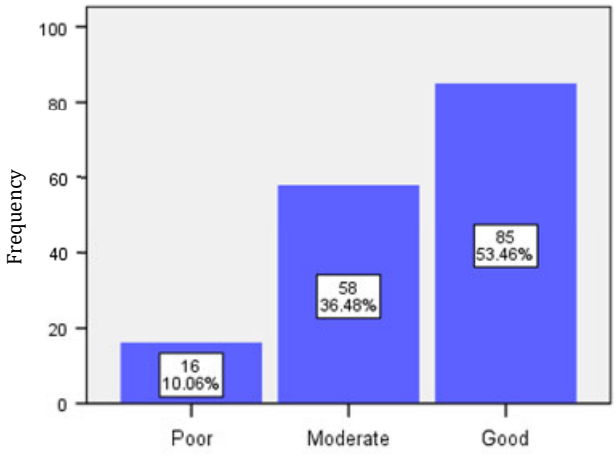

Figure 2: Classification of Participants (Working in Departments Dealing with Radiology) According to Knowledge

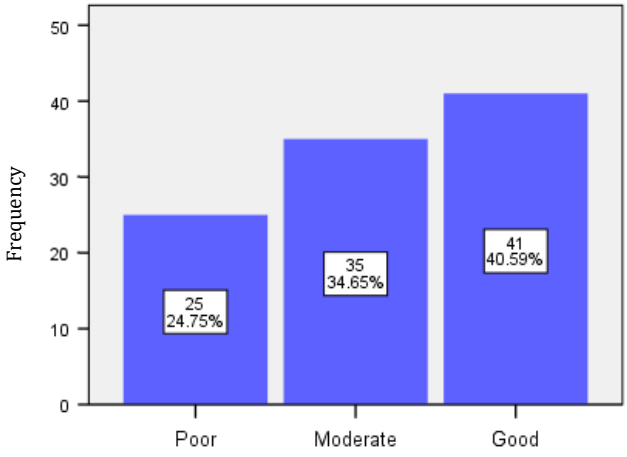

Figure 3: Classification of Participants (Working in Departments Not Dealing with Radiology) According to Knowledge

radiation exposure in the workplace? (answered with yes by 85.1%); Are you familiar with the necessary Personal Protective Equipment (PPE) used for radiation protection? (69.3%); Are you aware of the local regulations and guidelines on radiation safety? (62%). However, the ideal answer was chosen by less than half of the participants in two questions, namely: Do you know the basic principles of radiation safety, such as the ALARA principle (as Low as Reasonably Achievable)? (39.6%); Do you know how to respond to incidents involving radiation exposure in the workplace? (35.6%). We may notice that these statistics are reflected in their relatively lower average knowledge scale (M = 2.92, SD = 1.67), as compared to the first group. Figures 2-3 also reflect the relative superiority (in knowledge) of the first group over the second, where they proportion of poor-knowledge is lower in the first group (10.06%, as compared to 24.75% in the second group), while the

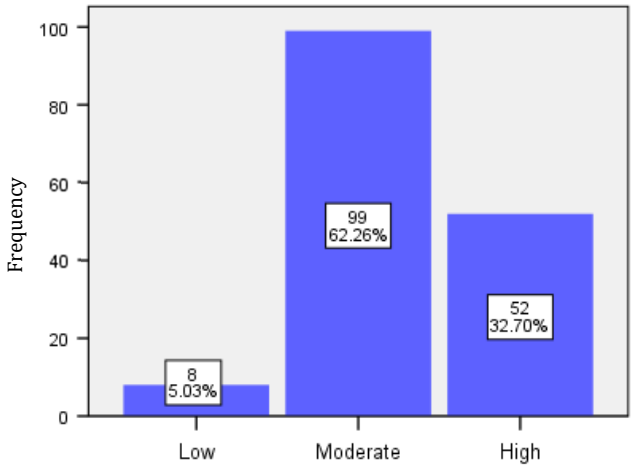

Figure 4: Classification of Participants (Working in Departments Dealing with Radiology) According to Practice

proportion of good-knowledge is higher in the first group (53.46%, as compared to 40.59% in the second group). Therefore, the average knowledge of both groups is considered moderate range.

Practice (Only for Those Working in Departments Dealing with Radiation)

Most of the participants (78-89%) have chosen the ideal answer (practice) in 3 out 5 f the questions, namely: Do you adhere to maintaining a safe distance from the radiation source? (89.3% answered with "yes"); Do you comply with the radiation safety procedure? (83.6% answered with "yes"); Do you accompany patients during radiological procedures? (78% answered with "yes"). On the other hand, less than half of the participants have chosen the right practice in 2 out of the 5 questions, namely: Do you find it challenging to implement radiation safety measures due to daily nursing tasks? (35.8% answered with "no"); Do you face challenges in following radiation safety procedures when working with imaging equipment? (31.4% answered with "no"). Finally, the average practice score is 3.18 (SD = 1.05), which indicates that a participant, on average, chooses 3 of the right practices out of 5 listed. Figure 4 shows that most of the participants (n = 99, 62.26%) have a moderate level of practice (the rest have mostly high level of practice) (Table 3).

Table 4 shows that the majority of the participants (92-95%) agreed on the following:

- That continuous education and training on radiation safety would help reduce risks in the workplace (94.6% agreed)
- That the availability of personal protective equipment and safety tools in the workplace would enhance radiation safety (94.2%)
- That continuous supervision contributes to improving radiation safety in the workplace (93.8%)

Table 3: The Practice of Participants in Radiation Safety

Question	Answer			
	No		Yes	
	N	%	N	%
Do you find it challenging to implement radiation safety measures due to daily nursing tasks?	57	35.8	102	64.2
Do you adhere to maintaining a safe distance from the radiation source during imaging procedures?	17	10.7	142	89.3
Do you comply with radiation safety procedures, including consistently wearing personal protective equipment (such as a lead apron) when working around radiation?	26	16.4	133	83.6
Do you face challenges in following radiation safety procedures when working with imaging equipment, especially in cases requiring portable X-ray use?	50	31.4	109	68.6
Do you accompany patients during radiological procedures such as portable x-ray ,CT or MRI?	35	22.0	124	78.0
Overall Score	3.18 (SD = 1.05) or 63.65 (SD = 20.97) in 100% scale			

Table 4: Agreement of Participants on Some Suggestions

Question	Answer			
	No		Yes	
	N	%	N	%
Do you think continuous education and training on radiation safety would help reduce risks in the workplace?	14	5.4	246	94.6
Do you believe that the availability of personal protective equipment and safety tools in the workplace would enhance radiation safety?	15	5.8	245	94.2
In your opinion, can continuous supervision contribute to improving radiation safety in the workplace?	16	6.2	244	93.8
Do you think raising awareness through posters or educational booklets in the workplace can improve radiation safety?	20	7.7	240	92.3
Do you think integrating radiation safety topics into nursing school curricula would improve awareness among future nurses?	16	6.2	244	93.8

Table 5: Mean and SD of the scores

Score of:	Mean	SD
Knowledge about nursing working in department dealing with radiation (Original scale)	3.63	1.45
Knowledge about nursing working in department dealing with radiation (100%-scale)	72.58	28.95
Knowledge about nursing working in department not dealing with radiation (Original scale)	2.92	1.67
Knowledge about nursing working in department not dealing with radiation (100%-scale)	58.42	33.43

- That raising awareness through posters or educational booklets in the workplace can improve radiation safety (92.3%)
- That integrating radiation safety topics into nursing school curricula would improve awareness among future nurses (93.8%)

The Association between Knowledge and Education/ Experience

For Participants Working in Departments Dealing with Radiation: The association between knowledge and education is statistically not significant (p-value >0.05) and this is reflected in what Figure 5 displays; the distribution of knowledge levels is similar across all educational levels (the distribution is roughly the same as the overall distribution of knowledge shown previously in Figure 2). Similarly, experience is not significantly associated with knowledge (p-value >0.05) and this is again reflected in what Figure 6 displays; the distribution of knowledge levels is similar across all experience levels.

For Participants Working in Departments Not Dealing with Radiation

There is a significant but negative association between knowledge and education (p-value <0.05) and this is clearly reflected in what Figure 7 displays: nursing interns have the highest proportion of good-knowledge (57.6%), then diploma and bachelor come next (41.7% and 37% respectively) and lastly those with higher education have none with good-knowledge (0%).

There is a significant association between knowledge and experience (p-value <0.05) and this is clearly reflected in what Figure 8 displays: it can be seen that those with lower experience (<6 years) have higher proportion of good-knowledge (around 46-47%), as compared with those with higher experience (the proportion of good-knowledge is around 19-20%).

The Association between Practice and Education/ Experience

The association between practice and education is statistically not significant (p-value >0.05) and this is somewhat reflected in what Figure 9 displays; the distribution of practice levels is similar across all educational levels (the distribution is roughly the same as the overall distribution of practice shown previously in Figure 4). However, the association between practice and experience is statistically significant (p-value <0.05) and this is somewhat reflected in what Figure 10 displays: the proportion of high-practice is roughly increasing, where it starts at 20.8% for those with <1 year of experience, then it increases to 30.6% for those with 1-5 years, then 46-56% for those with higher experience.

Score Statistics

Table 5 shows that the average knowledge score regarding working in a department dealing with radiation is 3.63 (SD =1.45), which corresponds to 72.58 (SD = 28.95) on the 100%-scale. The average of 72.58 tells us that a participant is expected to solve 72.58% of the

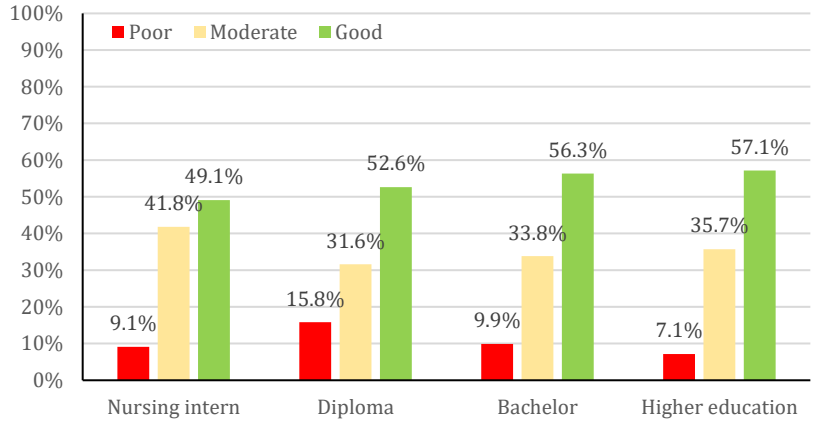

Figure 5: The Association between Knowledge and Education
(X^2 = 0.457, p>0.05)-for Participants Working in Departments Dealing with Radiation

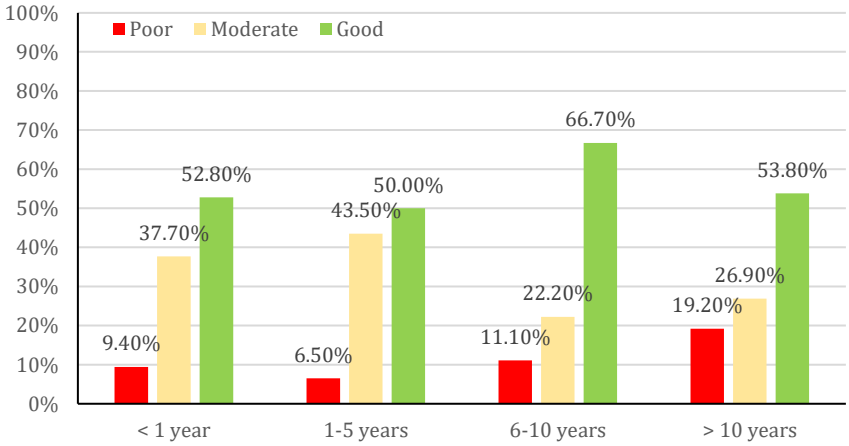

Figure 6: The Association between Knowledge and Experience
(X^2 = 0.821, p>0.05)-for Participants Working in Departments Dealing with Radiation

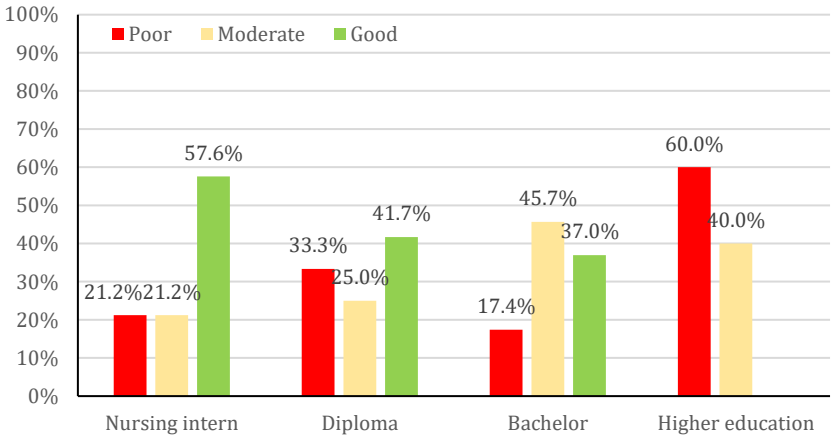

Figure 7: The Association between Knowledge and Education
(X^2 = 5.957, p≤0.05)-for Participants Working in Departments Not Dealing with Radiation

questions ideally (with "yes"). When classifying participant scores into poor (10.06%), moderate (36.48%) and good (53.46%), it can be seen that half of the participants (n = 85, 53.46%) have good knowledge (most of the remaining have moderate knowledge-level), see Figure 2. The average knowledge score regarding not working in departments dealing with radiation is 2.92 (SD = 1.67), which corresponds to 58.42 (SD = 33.43) on

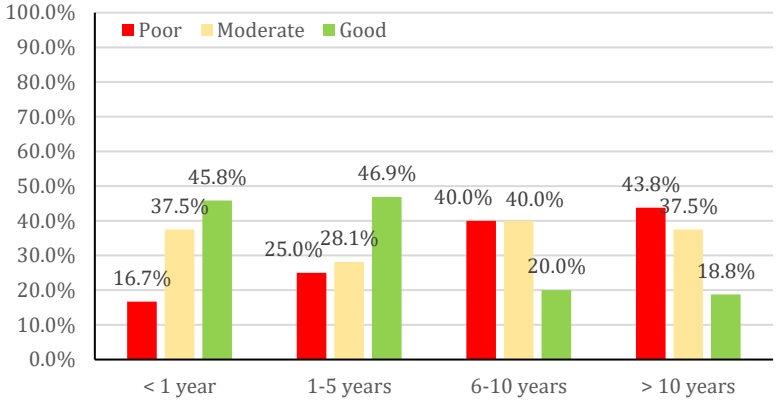

Figure 8: The Association between Knowledge and Experience
(X^2 = 6.148, p≤0.05)-for Participants Working in Departments Not Dealing with Radiation

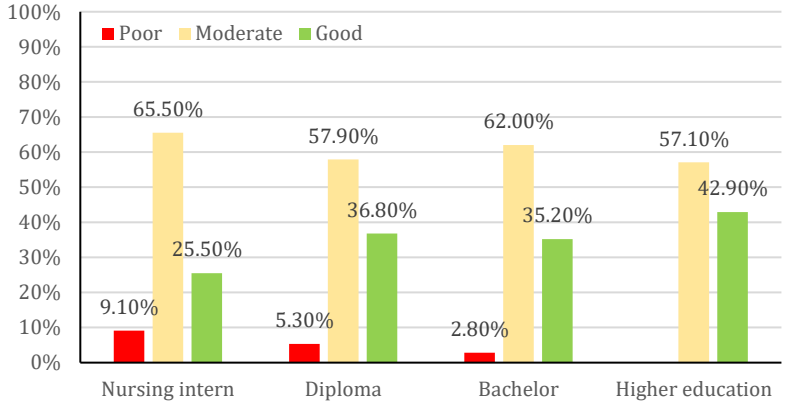

Figure 9: The Association between Practice and Education
(X^2 = 4.969, p>0.05)

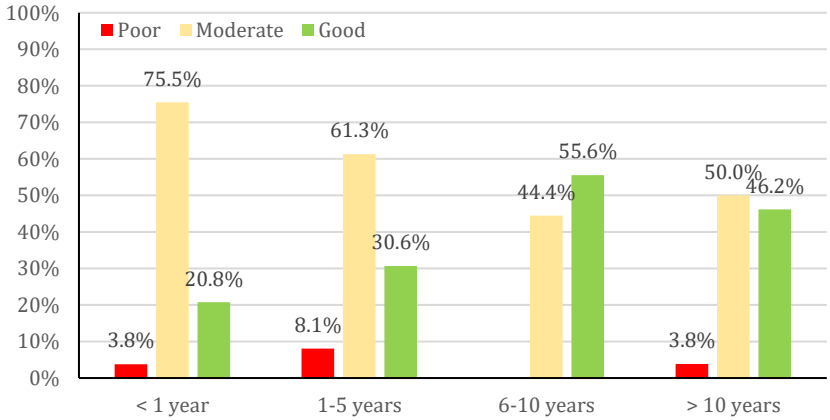

Figure 10: The Association between Practice and Experience
(X^2 = 12.025, p≤0.05)

the 100%-scale. The average of 58.42 lies in the "good knowledge" (40.59%) and it tells us that a participant is expected to solve 58.42% of the questions ideally (with "yes"). This actually matches the results shown in Figure 3 [classifying scores into poor (24.75%), moderate (34.65%) and good (40.59%)], where most of the participants were classified as having good knowledge (n = 41, 40.59%).

DISCUSSION

This study investigated Saudi nurses' knowledge and practices regarding radiation safety and explored the influence of various factors, including clinical department, educational level and years of experience. The findings indicate that most Saudi nurses possess moderate to high levels of knowledge related to radiation protection, with 48.65% demonstrating good knowledge,

35.9% moderate knowledge and only 15.8% showing poor knowledge. Notably, these results contrast with earlier studies conducted in different regional contexts. For example, research among Jordanian cardiac unit nurses reported generally low levels of knowledge regarding interventional radiation safety practices and the availability of protective measures [2]. Similarly, a study carried out in a large tertiary medical center revealed limited awareness and understanding of ionizing radiation risks among healthcare personnel, further highlighting the variability of knowledge across different settings [35].

The current study also found that nurses working in radiation-exposed departments had significantly higher knowledge scores (M = 3.63, SD = 1.45) compared to their counterparts in non-radiology units (M = 2.92, SD = 1.67). Awareness of the ALARA principle was more prevalent among radiology nurses (62.3%) than non-radiology nurses (39.6%). Furthermore, 56% of nurses in radiology departments reported knowing how to respond to radiation exposure incidents, while a substantial proportion of non-radiology nurses (64.4%) lacked sufficient knowledge or confidence to act appropriately. These findings are consistent with prior research indicating that nurses directly involved in radiological procedures tend to possess higher levels of radiation knowledge and demonstrate stronger safety behaviors, reported a significant positive relationship between radiation knowledge and safety behavior ($\beta = 0.495$, $p<0.005$), as well as between knowledge and radiation protection practices ($\beta = 0.239$, $p<0.001$), suggesting that knowledge acquisition enhances compliance with safety protocols [36]. Despite this, the current findings underscore the need for standardized radiation safety training across all nursing departments. While radiology nurses exhibited stronger knowledge, their actual adherence to comprehensive safety practices was not optimal. Although a high percentage of nurses adhered to basic protective behaviors such as maintaining distance from radiation sources (89.3%) and using PPE (83.6%), the overall practice score (M = 3.18, SD = 1.05) indicates that only three out of five essential safety measures were consistently followed during clinical routines.

Another key factor influencing safety practices is clinical experience. Nurses with longer years of service showed stronger compliance with radiation safety guidelines, especially those working outside radiology departments. This observation is supported by a recent Egyptian study, in which more experienced healthcare workers demonstrated greater adherence to radiation safety protocols [9]. In Saudi Arabia, a study of nurses in nuclear medicine departments found that those who had attended training or had longer experience scored higher in awareness, though their actual safety practices remained suboptimal [34]. Nevertheless, a considerable proportion of participants in recent studies (over 40%) reported barriers to consistently applying safety protocols, citing high workload, limited access to PPE and lack of administrative support [34,37].

Encouragingly, strong support was expressed by many nurses for measures to strengthen the radiation safety culture. In the Egyptian study, a large majority advocated for continuous education, improved access to protective tools and enhanced supervision [9]. In the Saudi nuclear medicine context, many participants recommended integrating radiation safety topics into nursing curricula, regular training and improved availability of PPE [34]. Collectively, these findings underscore the need for a comprehensive approach: Ensuring that all nurses-regardless of their department-are trained, supervised and institutionally supported to apply radiation safety protocols in practice.

CONCLUSIONS

This study provides valuable insights into the current state of radiation safety knowledge and practices among Saudi nurses. The results reveal that while a substantial proportion of nurses possess moderate to good theoretical knowledge, gaps remain in the consistent and comprehensive application of radiation safety protocols, particularly among those working outside radiology departments. Clinical experience, departmental assignment and prior training emerged as key factors influencing both knowledge and compliance. These findings are consistent with previous literature, which emphasizes that experience and targeted education enhance radiation safety behaviors among healthcare professionals [9,34].

However, the persistence of institutional barriers such as inadequate access to protective equipment, limited ongoing training opportunities and a lack of formal supervision continues to hinder full compliance with established safety standards [38,39]. The strong support expressed by participating nurses for structured educational programs, availability of PPE and regular supervision underscores the urgent need for systemic reforms.

To bridge the gap between knowledge and practice, healthcare institutions should adopt a comprehensive and inclusive approach to radiation safety training, ensuring that all nurses, regardless of department, are adequately equipped to work safely in environments involving ionizing radiation. Incorporating radiation safety topics into nursing curricula, reinforcing hands-on training and ensuring administrative support are crucial steps toward cultivating a sustainable safety culture in clinical settings [40,41].

Future research should explore the long-term impact of continuous education programs and evaluate the effectiveness of institutional interventions in improving compliance across diverse clinical environments. A national framework for radiation safety in nursing practice may further standardize competencies and reduce occupational exposure risks.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

Enhance Training Programs

Healthcare and academic institutions should develop and implement educational programs tailored to improve nurses' understanding of radiation safety standards across various clinical settings-not solely within radiology departments. These programs should be context-specific and aligned with nurses' actual working environments.

Launch Awareness Campaigns

Healthcare organizations are encouraged to initiate awareness campaigns that highlight the risks associated with radiation exposure and promote best practices for radiation safety. These campaigns should emphasize the long-term health risks and provide practical guidelines for safe conduct in environments where radiation is present.

Develop Pre-Exposure Screening Protocols

Standardized pre-exposure screening protocols should be established and uniformly implemented across healthcare facilities. These protocols are essential for identifying and mitigating potential hazards before healthcare personnel, especially nurses, are exposed to medical radiation.

Promote Research and Continuous Improvement

Further research is needed to explore additional factors that may influence healthcare workers' knowledge, attitudes and behaviors regarding radiation safety. Moreover, continuous evaluation and enhancement of training programs and safety protocols are crucial to keeping pace with technological advancements and evolving clinical practices

Limitations

This study provides valuable insights into Saudi nurses' knowledge and radiation safety practices within healthcare settings. However, several limitations should be considered when interpreting the findings. First, the study sample was restricted to Saudi nurses, which may limit the generalizability of the results to other healthcare professionals, such as radiologic technologists, radiologists or non-Saudi nurses. Second, the data collection method relied on self-administered online questionnaires, which may have introduced certain biases, including variability in participants' comprehension of the questions, lack of verification of respondent identity and potential inaccuracies in self-reported data. Furthermore, the study utilized a cross-sectional design, preventing the assessment of changes in knowledge or practices over time. Additionally, the use of digital tools for data collection may have excluded individuals without internet access or adequate digital literacy, thereby potentially affecting the representativeness of the sample.

Ethical Consideration

Ethical approval for this study was obtained from the University of Jeddah (UJ) prior to data collection, in compliance with the university's research ethics standards. Informed consent was secured from all participants on the first page of the questionnaire after explaining the purpose of the study and emphasizing their voluntary participation and right to withdraw at any time without consequences. Adequate time was given to respondents to complete the questionnaire and the researcher ensured that there was no pressure on participants to take part in the study. All data collected were treated anonymously.

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