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Research Article

Radiation Hazard Awareness Among Healthcare Workers in Nyeri County, Kenya

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Abstract

The widespread use of radioactive equipment in hospitals necessitates adequate knowledge and tools among healthcare workers to prevent and monitor radiation exposure. The study investigated the effectiveness of radiation protection in the detection of exposures among healthcare workers in Nyeri County, Kenya, focusing on radiation exposure levels, level of awareness, and control measures. Using a cross-sectional design, the study targeted 1121 healthcare workers, with a sample of 294. Data was collected through semi-structured questionnaires and a checklist, generating both quantitative and qualitative data. Dosimeter read-outs were conducted for one month and a radiation safety assessment survey in the Radiology department was also conducted using a radiation detector meter. Quantitative data were analyzed using SPSS version 27, employing descriptive and inferential statistics, while qualitative data were analyzed thematically. Findings revealed that about half of the healthcare workers had not received training on radiation hazards, and less than half were aware of the maximum permissible dose limit for adults. Approximately half of the workers knew that the eyes, thyroid glands, ovaries, and testis are susceptible to radiation hazards. The study recommended comprehensive and regular training programs for all healthcare workers, emphasizing the correct handling of lead aprons and the consistent use of personal protective devices such as lead aprons, lead glasses, portable lead shields, automatic interlock devices, and thyroid shields.

Keywords

Healthcare Workers, Radiology, PPE, Radiation Hazards, Permissible Dose, Radiation Exposure

1. Introduction

Radiology is a crucial diagnostic tool for many diseases and plays a significant role in monitoring treatment and predicting outcomes (Kaya et al., 2017) [1]. Annually, over 3.6 billion diagnostic radiology exams, 37 million nuclear medicine procedures, and 7.5 million radiotherapy treatments are performed worldwide (Miyazaki, 2019) [2]. Common diagnostic imaging techniques include X-rays, CT scans, fluoroscopy, and mammograms (Parikh et al., 2017) [3]. These techniques improve health outcomes, save lives, and may reduce healthcare costs (Ko et al., 2017) [4].

Healthcare workers are regularly exposed to high doses of radiation, with about 22.8 million workers globally exposed to ionizing radiation. Beyond certain thresholds, radiation can impair tissue and organ function, causing acute effects like skin redness, hair loss, radiation burns, acute radiation syndrome, and long-term effects such as gene mutation, cancer, cataracts,

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bone and blood cell destruction, and death (Runyan, 2018) [5].

Control measures are based on individual-related Radiation Protection (RP) principles (dose limits) and source-related RP principles, including justification of practices/procedures and optimization of protection using the "as low as reasonably achievable" (ALARA) principle (Land et al., 2010) [6]. Basic protective measures include time, distance, and shielding. However, radiation safety awareness among healthcare workers remains low (Kaya et al., 2017) [1].

The concept of a radiation protection culture (RPC) in radiology departments, which combines attitudes, beliefs, practices, and rules, is discussed in the study by Ploussi and Efstathopoulos (2016) [7]. They emphasize the importance of establishing such a culture to enhance radiation safety and minimize risks. The International Atomic Energy Agency (IAEA) has been working with several African countries to strengthen regulatory infrastructure, which includes implementing DRLs, quality assurance programs, and other radiation protection measures. However, both hospital authorities and department heads often ignore radiation protection principles (Alsafi, 2016) [8]. In Nigeria, proactive steps are needed to improve radiographers' knowledge of proper radiation protection practices (Kaya et al., 2017) [1].

In Kenya, studies have assessed radiation exposure in various contexts. Ruth et al., (2020) [9] examined ionizing radiation levels in Nyamira County quarries; Musamali (2017) [10] assessed human exposure to natural radiation sources in Bungoma County; and Kamunde (2018) [11] examined radiation exposure from construction sand in Tharaka-Nithi County. However, there are limited empirical studies on radiation exposure in health facilities in Nyeri County. This study aims to assess the level of awareness of the radiation hazards among healthcare workers in Nyeri County, Kenya.

Kenya, a developing nation, has about 1,000 radiation-producing facilities, with 80% used for medical applications (Ministry of Health, 2019) [12]. These include around 500 large X-ray machines, 150 for dental imaging, 27 CT scanners, 18 mammography and bone densitometer units, 3 cobalt radiotherapy units, 3 Linac accelerators, over 100 fluoroscopy units, 5 interventional units, 2 brachytherapy units, and 3 gamma cameras (Ministry of Health, 2019) [12]. Medical use accounts for the largest proportion of ionizing radiation in Kenya (Abuelhia & Alghamdi, 2020) [13].

Research indicates that while radiation exposure levels among medical staff generally fall within international safety limits, there is significant variation across different roles and facilities (Korir et al., 2007) [14]. This highlights the need for localized studies to understand specific exposure patterns in Kenyan hospitals. Systematic reviews, such as Gbetchedji et al., (2020) [15], show that dosimetric monitoring can significantly limit radiation exposure and reduce health risks, but data from Africa is sparse. Additionally, while Kenyan healthcare workers generally understand radiation risks, detailed knowledge of protective measures and their consistent application is lacking (Mulunda et al., 2013) [16].

Evaluating current practices in Nyeri County hospitals will provide insights into the adequacy of protective measures, identify gaps in training and compliance, and inform policy improvements to enhance worker safety.

Ideally, healthcare workers should be fully knowledgeable about radiation hazards and equipped with necessary tools and protective measures. However, in Nyeri County Hospitals, there has been a significant increase in radioactive equipment use, but many healthcare workers lack adequate knowledge of radiation safety and essential tools for protection and monitoring. This deficiency is due to insufficient training, limited provision of protective gear, and inconsistent integration of safety measures in clinical practice. Understanding the effectiveness of current radiation protection practices in Nyeri County is crucial to inform decision-making and develop strategies to improve awareness and enhance protective measures against radiation exposure.

2. Materials and Methods

2.1. Study Design

The study adopted a cross-sectional study design. The researcher measured the exposure levels. The design helped in determining the effectiveness of radiation protection in the detection of exposures among healthcare workers in Nyeri County, Kenya.

2.2. Study Area and Population

The County Government of Nyeri is one of the 47 Counties in the Republic of Kenya that was established under the constitution of Kenya 2010. Nyeri County is located in the central region of the country and covers an area of 3,337.2 Km^2. The County borders Laikipia County to the north, Kirinyaga County to the east, Murang'a County to the south, Nyandarua County to the west and Meru County to the northeast. Nyeri county has a population of 752, 695 (Nyeri County Government, 2020) [17].

The target population of the study were all 1121 staff working in the health facilities. The study population were 294 staff working in the health facilities Nyeri County, Kenya.

Inclusion criteria encompassed all the healthcare workers involved directly in the provision of healthcare services and those in health facilities for more than 6 months, while the exclusion criteria encompassed all the healthcare workers in health facilities for less than 6 months.

2.3. Sampling Method

Stratified random sampling method was adopted to choose a sample size from the target population. After categorization, a number proportional to the size of the stratum and, a random sample was acquired from each stratum when contrasted with the population (Kothari, 2012) [18]. In this research, the strata

were the health facilities in Nyeri county.

2.4. Sample Size Determination

Slovin's Formula (Slovin, 1960) [19] was used to determine the sample size for a population of 1,121 with a 5% margin of error, resulting in a sample size of 294 (n = 1121 / (1 + 1121 * 0.05^2)). The total sample size across all facilities was 294.

2.5. Data Processing and Analysis

A nominal scale and five-point Likert scale were used to collect data on training, maximum permissible dose limits, and organ radiation hazards. A drop-off and pick-up later method was used to administer questionnaires, with weekly follow-ups to ensure completion. A pre-test was conducted to identify and rephrase ambiguous questions, remove typographical errors, and ensure the relevance of questions. According to Egbert (2015) [20], a 10% pilot group was used to ensure a representative sample size. Validity was ensured through pre-testing, supervisor review, and standard interview guides, with input from professionals in the field of occupational safety and health (Kothari, 2012) [18].

A pre-test was used to test the reliability of the research instruments. An internal consistency technique was applied using Cronbach's Alpha. The alpha value ranges between 0 and 1 with reliability increasing with the increase in value. According to Kothari, (2012) [18], Cronbach's Alpha coefficient of 0.6-0.7 is a commonly accepted rule of thumb that indicates acceptable reliability and 0.8 or higher indicates good reliability. In this study, 0.7 Cronbach's Alpha was considered acceptable.

The study employed a semi-structured questionnaire to collect both quantitative and qualitative data, which was analyzed using thematic analysis and narrative presentation. Quantitative data was analyzed using descriptive statistics, including frequency distribution, percentages, mean, and standard deviation, to assess radiation exposure levels, awareness of hazards, and control measures applied by staff. Inferential statistics, including chi-square (X2), were used to examine the relationship between awareness, radiation use in the radiology department, and healthcare workers' exposure to radiation (Creswell, 2014) [21]. The results were presented in tables and figures through bar charts and pie charts, with a confidence level of 95% and a significance level of 0.05. This indicates that a significant relationship between independent variables and the dependent variable requires a p-value below 0.05.

3. Results and Discussion

3.1. Training on Radiation Hazards

The respondents were asked to indicate whether they had gone through any training on hazards of radiation. The results were presented in Figure 1.

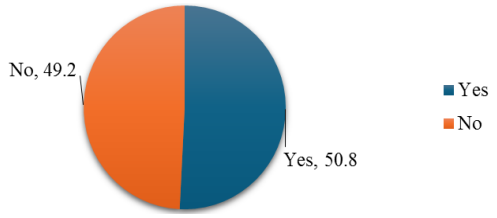

Figure 1. *Awareness Training on Radiation Hazards.*

Approximately half of the healthcare workers (50.8%) had received training on radiation hazards, while the other half (49.2%) had not. This aligns with previous research by Kaya et al., (2017) [22], which found that less than 50% of healthcare professionals in the Middle East had adequate knowledge of radiation risks and safety. These findings underscore the critical need for improved training and education in radiation safety to mitigate health risks associated with improper radiation use, as emphasized by the World Health Organization (2018) [23], which advocates for a public health strategy to manage and reduce radiation exposure risks. Enhanced training can help ensure that medical staff are well-informed about radiation safety practices, thereby protecting both patients and healthcare workers from potential adverse effects. These findings were also in line with Reagen and Slevhta (2010) [24] observation that most of the healthcare professionals working in hospitals had not been trained on radiation hazards. This significant gap in training suggested a need for comprehensive educational initiatives to ensure all healthcare workers were adequately informed about radiation safety.

3.2. Training on Radiation Hazards by Gender

The study assessed the awareness of radiation hazards training by gender among healthcare workers in Nyeri County. Respondents were asked whether they had undergone training on the hazards of radiation. The results were presented in table 1.

Table 1. *Training on Radiation Hazards by Gender.*

	Yes	No
Male	53.3%	46.7%
Female	48.0%	52.0%

In relation to gender, 53.3% of male and 48.0% of female healthcare workers received radiation hazard training. This result indicates that both male and female healthcare workers require more targeted training to improve awareness and safety practices regarding radiation hazards.

Age Bracket

Table 2 below illustrates the distribution of healthcare workers who had undergone training on radiation hazards, categorized by age bracket.

Table 2. *Training on Radiation Hazards by Age Bracket.*

	Yes	No
18 Years and below	0.0%	0.0%
19-30 years	57.8%	42.2%
31-42 Years	48.6%	51.4%
43 Years and above	28.2%	71.8%

In relation to the age bracket, younger workers (19-30 years) had higher training rates (57.8%) compared to those aged 43+ (28.2%). This disparity highlights the need for ongoing training opportunities, especially for older staff, to ensure comprehensive radiation safety awareness across all demographics.

The highest percentage of trained staff was in the 19-30 years age bracket (57.8%). For the 31-42 years bracket, 48.6% had received training. Among staff aged 43 years and above, only 28.2% have undergone training. These findings suggest younger healthcare workers were more likely to have received training on radiation hazards, indicating a need for increased training opportunities for older staff. This suggests a disparity in training opportunities that leaves older staff less prepared to handle radiation hazards, highlighting the need for comprehensive training programs across all age groups. This finding aligns with the literature, particularly with Dehghani (2015) [25], who emphasizes the necessity of radiation safety education to mitigate health risks associated with improper radiation use. The World Health Organization (2018) [23] supports this, stressing that managing radiation hazards requires a public health strategy to minimize risks and maximize benefits, reinforcing the importance of continuous training for all healthcare workers to ensure safety and effectiveness in radiation use.

Nature of Work

Table 3 below represents the distribution of healthcare workers who have undergone training on radiation hazards, categorized by their nature of work.

Table 3. *Training on Radiation Hazards by Nature of Work.*

	Yes	No
Doctors	55.6%	44.4%
Nurses	50.5%	49.5%
Radiologists	75.0%	25.0%
Pharmacists	33.3%	66.7%
Biomedical Engineers	42.9%	57.1%
Others	51.8%	48.2%

In relation to the nature of work, doctors showed balanced awareness with 55.6% trained, while nurses had nearly equal figures (50.5% trained). Radiologists led with 75.0% trained, reflecting the critical importance of safety in their role. Pharmacists (33.3%) and biomedical engineers (42.9%) had lower training rates, highlighting significant gaps. These disparities emphasize the need for targeted educational initiatives to enhance radiation safety awareness across different healthcare professions.

The study's findings indicate significant disparities in radiation hazard training among different healthcare professions, highlighting a critical need for targeted educational initiatives to enhance radiation safety awareness. Specifically, while radiologists demonstrate the highest level of training (75%), professionals like pharmacists and biomedical engineers exhibit significantly lower training rates (33.3% and 42.9%, respectively). This uneven distribution of training underscores potential gaps in occupational health safety across the healthcare sector, potentially affecting overall preparedness. Studies like Nassef and Kinsara (2017) [27] and Ahmad et al., (2019) [26] emphasize the importance of proper training and monitoring to mitigate health risks associated with radiation exposure. This comprehensive assessment aligns with previous research, indicating a consistent need for enhanced radiation safety training across various healthcare roles to ensure a uniformly high standard of occupational safety and health.

Table 4. *Chi-Square Test Results for Training on Radiation hazards by nature of work among healthcare workers.*

	Chi-Square Tests		
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	8.075a	5	.152
Likelihood Ratio	8.353	5	.138
Linear-by-Linear Association	.179	1	.673
N of Valid Cases	258		

2 cells (16.7%) have expected count less than 5. The minimum expected count is 4.43.

The Chi-Square test results indicated no significant association between the variables studied. The Pearson Chi-Square value of 8.075 with 5 degrees of freedom and a p-value of 0.152, along with the Likelihood Ratio Chi-Square of 8.353 (p = 0.138), suggest no statistically significant relationship at the 5% significance level. These findings emphasize the need for improved radiation safety training across different age groups and professions among healthcare workers.

3.3. Awareness of Maximum Permissible Dose Limit

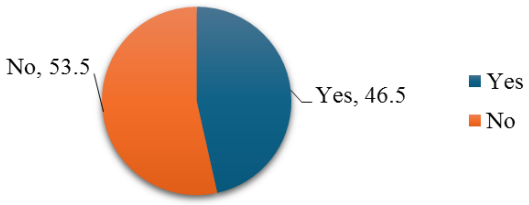

Figure 2. *Awareness of Maximum Permissible Dose Limit.*

The study found that 46.5% of participants were aware of the maximum permissible dose limit for adult radiation workers, while 53.5% were not. This significant gap in awareness is concerning, given the potential health risks associated with radiation exposure, such as cell damage and increased cancer risk. Previous studies, like those by Lee et al,. (2018) [28], emphasize the elevated cancer risks among medical radiation professionals due to insufficient awareness and protection practices. Nassef and Kinsara (2017) [27] also highlight the need for better training, despite average radiation doses being below recommended limits, as consistent monitoring and education are essential for maintaining safety.

3.4. Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Gender

Table 5. *Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Gender.*

	Yes	No
Male	48.1%	51.9%
Female	44.7%	55.3%

By gender, 48.1% male respondents were aware of the maximum permissible dose limits, while 51.9% were not. For female respondents, 44.7% were aware, and 55.3% were unaware. This close division in awareness levels suggests a general need for enhanced training and awareness programs about radiation safety across both genders. These findings align with previous research indicating widespread lack of radiation safety knowledge among healthcare workers, such as Kaya et al. (2017) [22].

Age Bracket

Table 6. *Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Age Bracket.*

	Yes	No
18 Years and below	0.0%	0.0%
19-30 years	56.5%	43.5%
31-42 Years	38.9%	61.1%
43 Years and above	23.1%	76.9%

The study found that the age group 19-30 years had the highest awareness (56.5%) of the maximum permissible dose limit, indicating effective early training. However, 43.5% of this group was still unaware, showing room for improvement. For the 31-42 age group, only 38.9% were aware, while 61.1% were not, suggesting a need for refresher training. Among those aged 43 and above, only 23.1% were aware of the dose limits, with 76.9% unaware, highlighting a critical gap in knowledge that could impact safety practices. These findings suggest that while younger professionals are more informed, there is a persistent knowledge gap even among them, and older professionals exhibit a critical lack of awareness that could jeopardize safety practices. These finding correlate with Kaya et al., (2017) [22] study, which found that radiation safety awareness among healthcare workers in Middle Eastern countries was often inadequate, highlighting the need for continuous education across all age groups. The study implies that ongoing refresher training and targeted educational interventions are essential to address these knowledge gaps and enhance safety practices in radiation-related fields.

Nature of Work

Table 7. *Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Nature of Work.*

	Yes	No
Doctors	77.8%	22.2%
Nurses	51.5%	48.5%
Radiologists	65.0%	35.0%
Pharmacists	28.6%	71.4%
Biomedical Engineers	32.1%	67.9%

	Yes	No
Others	42.2%	57.8%

The findings reveal a significant variance in awareness regarding the maximum permissible dose limits for adult radiation workers across various healthcare professions. While doctors and radiologists showed relatively high awareness levels of 77.8% and 65.0% respectively, the understanding among nurses (51.5%), pharmacists (28.6%), and biomedical engineers (32.1%) substantially lagged. This disparity calls for targeted educational interventions, particularly for the latter groups, to enhance awareness of radiation safety protocols, thus serving as a foundation for safer healthcare practices (Erkan et al., 2019 [30]; Kaya et al., 2017 [22]). Linking these findings to the Social Cognitive Theory (SCT), it is evident that the professionals' awareness levels may reflect their experiences and training opportunities, which directly influence self-efficacy and behavior in radiation safety practices (Miyazaki, 2019) [2]. The Italian Workers' Model further emphasizes the importance of active participation and training in health and safety, suggesting that systemic measures, like regular workshops and policy enforcement, are essential to improve safety practices among less aware healthcare workers (Cecchini et al., 2017 [33]; Ploussi & Efstathopoulos, 2016) [7]. Together, these insights underscore a critical need for comprehensive safety education initiatives within the healthcare sector to mitigate radiation exposure risks.

Table 8. *Chi-Square Tests for Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Nature of Work.*

	Chi-Square Tests		
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	12.942 [a]	5	.024
Likelihood Ratio	13.287	5	.021
Linear-by-Linear Association	5.232	1	.022
N of Valid Cases	258		

a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is 4.19.

The Chi-Square test results indicated a significant relationship between the variables studied. The Pearson Chi-Square value of 12.942 with 5 degrees of freedom and a p-value of 0.024, along with the Likelihood Ratio Chi-Square of 13.287 (p = 0.021), suggests a statistically significant association at the 5% significance level. The Linear-by-Linear Association value of 5.232 (p = 0.022) also indicates a significant linear relationship. However, 16.7% of the cells had an expected count less than 5, which might affect the robustness of the test results.

These findings suggest that awareness of radiation safety protocols is significantly associated with the nature of work, emphasizing the need for tailored training programs to enhance radiation safety awareness across different healthcare professions.

These results suggest that the observed categorical variables do not behave independently, implying that specific factors can influence behavior and outcomes related to health and safety in the context of radiation exposure, aligning with Social Cognitive Theory (SCT), which emphasizes the interplay of personal experiences, environmental influences, and behavior change. The significant Linear-by-Linear Association (p = .022) indicates that there is a systematic relationship between the variables, further supporting the premise that increased awareness and training on radiation safety can enhance self-efficacy and proactive behavior among hospital staff (Cecchini et al., 2017 [33]; Giraudo et al., 2017) [31]. However, the caveat of 16.7% of cells having expected counts below 5 raises concerns about the reliability of these results, as per the literature (Cho et al., 2018) [29]. This aligns with previous studies indicating that while awareness of radiation hazards is crucial in reducing exposure, gaps still exist in the knowledge and adherence to safety practices among healthcare workers (Reagen & Slevhta, 2010 [24]; Kaya, et al., 2017) [22], which underscores the need for continuous training and reinforcement of safety measures in medical settings.

Level of Education

Table 9. *Awareness of Maximum Permissible Dose Limit for Adult Radiation Workers by Level of Education.*

	Yes	No
PhD	50%	50%
Master’s Degree	75%	25%
Bachelor's Degree	50.4%	49.6%
Diploma	41.7%	58.3%
Certificate	30%	70%
Secondary	23.5%	76.5%

The study reveals a clear association between higher educational attainment and increased awareness of radiation safety standards. Specifically, those with a master's degree exhibited the highest awareness (75%), while secondary education holders demonstrated a significant knowledge gap, with only 23.5% aware of the limits. This finding highlights the critical role that education plays in understanding and

adhering to safety regulations. For instance, the results align with Kaya, et al. (2017) [22], who found that healthcare professionals in Middle Eastern countries often had low levels of radiation safety awareness, underscoring the need for improved education and training. Targeted educational programs and continuous professional development are essential to elevate the understanding of radiation safety across all levels of education, particularly among less-educated staff, to ensure comprehensive safety compliance and mitigate risks associated with radiation exposure. The results highlight the importance of academic training in enhancing radiation safety awareness and practices among healthcare professionals Safi et al., (2014) [32]

Table 10. *Chi-Square Test Results for Awareness of Maximum Permissible Dose Limits.*

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.305 [a]	1	.581		
Continuity Correction[b]	.182	1	.669		
Likelihood Ratio	.305	1	.581		
Fisher's Exact Test				.618	.335
Linear-by-Linear Association	.304	1	.582		
N of Valid Cases	258				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 57.21.
b. Computed only for a 2x2 table

The Pearson Chi-Square result of 0.305 with a p-value of 0.581 suggests no significant association between awareness of permissible dose limits and the studied factors. This indicates that the level of awareness about radiation dose limits does not significantly impact the observed variables. This finding aligns with the literature, particularly with the study by Kaya et al., (2017) [22], which reported low levels of radiation safety awareness among healthcare workers in Middle Eastern countries. This underscores the need for improved education and training programs to enhance awareness of radiation safety and dose limits. The study highlights that despite the established risks associated with radiation, such as those outlined by the World Health Organization (2018) [23] and supported by previous research (e.g., Lee, Choi & Ko, 2018) [28], there remains a gap in effective awareness and implementation of safety measures, suggesting that increased educational efforts are essential for mitigating these risks. This suggests that awareness levels are consistent across different demographics and work roles, emphasizing the need for generalized training across all groups.

3.5. Awareness of Organs Prone to Radiation Hazards

The study found that 80.2% of the healthcare workers were aware that eyes are prone to radiation hazards, 74% knew about the thyroid glands, and 82.9% were aware of the risks to ovaries and testis. This high level of awareness aligns with literature emphasizing the importance of education and training in safety practices. However, variability in awareness across different organs indicates knowledge gaps that require targeted training interventions. Enhanced awareness can improve self-efficacy and behaviors, suggesting that ongoing education can effectively mitigate radiation exposure risks.

This awareness aligns with literature that emphasizes the importance of education and training in fostering safety practices among medical professionals, as highlighted by social cognitive theory (Cecchini et al., 2017) [33]. The high awareness rates suggest that healthcare workers may possess a baseline understanding of radiation risks, yet the variability in awareness across different organs might indicate gaps in knowledge that need targeted intervention—probably through more focused training programs. Rodrigues et al., (2023) [34] review examines the knowledge of radiation protection among healthcare professionals exposed to ionizing radiation. It underscores the need for comprehensive education and training to ensure safety and reduce exposure risks. Furthermore, integrating elements of the Italian Workers' Model may provide a structured approach to addressing these hazards, emphasizing preventative measures over compensatory ones (Runyan, 2018) [35]. With varying degrees of awareness mirrored in international studies, like those in Middle Eastern and African countries, the implications of consistent training and evaluation are critical for optimizing radiation safety protocols globally (Muhogora & Rehani, 2017 [36]; Kaya et al., 2017) [22]. However, despite this awareness, the overall

training and knowledge on practical radiation safety measures appear insufficient. These findings agree with Paolicchi et al. (2016) [37] findings that radiation exposure affects the eyes and thyroid glands. The findings are also similar to a study by Alotaibi et al. (2017) [38], which highlights that despite awareness of radiation hazards, the overall training and practical knowledge on radiation safety measures among healthcare workers remain insufficient. The study also confirms that radiation exposure can significantly affect sensitive organs such as the eyes and thyroid glands.

Table 11. *Awareness of Organs Prone to Radiation Hazards.*

	Yes	No
The eyes	80.2%	19.8%
Thyroid gland	74%	25.6%
Ovary and testis	82.9%	17.1%

3.6. Awareness of Hazards of Radiation in Health Facilities

Table 12. *Awareness of hazards of radiation in health facilities.*

Statements	1	2	3	4	5	Mean	Std. Dev
After use, lead aprons for protection should be folded before collection	23	11	13	21	32	3.28	1.57
Workers should wear a thick lead apron as possible to reduce the radiation dose maximally	9.7	7	5.4	26	52	4.03	1.32
Lead goggles can reduce radiation exposure to personnel	10	3.9	12	26	48	3.98	1.29
Radiation measuring instrument must be placed outside of the lead apron	10	6.2	18	24	42	3.81	1.31
Radiation measuring instruments should be worn above the lead apron	16	11	19	21	33	3.44	1,45
Radiation measuring instruments should be worn under the lead apron	28	11	17	19	26	3.04	1.57

Scale indicator (1=Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree, 5=Strongly Agree)

Healthcare workers showed varying levels of awareness regarding radiation hazards in health facilities. Mean scores ranged from 3.04 to 4.03, with a standard deviation of 1.29-1.57, indicating some variation in understanding among staff. The highest agreement rates were for statements related to wearing lead aprons (51.9%), while the lowest were wearing a thick lead apron as possible to reduce the radiation dose maximally (9.7%). Staff recognized the importance of personal protective equipment but lacked understanding of radiation measuring instruments, potentially leading to inadequate exposure monitoring and patient safety issues.

This aligns with existing literature, such as findings by Safi et al. (2014) [32] and Yurt et al. (2014) [39], which emphasize the necessity of using personal protective equipment (PPE) to mitigate radiation exposure effectively and demonstrate the critical need for comprehensive training and awareness programs across all demographic groups. Additionally, the study's results resonate with the Social Cognitive Theory, highlighting that enhancing workers' self-efficacy and observational learning through consistent training can influence behavior change and reduce exposure risks. Furthermore, the Italian Workers' Model underscores the importance of proactive measures and worker engagement in safety practices, advocating for the establishment of a robust radiation protection culture within healthcare settings. These findings underscore the urgency for targeted educational programs that address identified knowledge gaps and reinforce best practices in radiation safety, ultimately ensuring both staff and patient well-being in medical environments.

4. Conclusion

The findings emphasize the necessity for improved training and awareness programs for all healthcare workers regarding radiation hazards, irrespective of role, gender, age, or education level, to reduce exposure risks and enhance safety. This aligns with existing literature, which stresses the importance of personal protective equipment and comprehensive training. Consistent training improves self-efficacy and behavior change, advocating for a strong radiation protection culture in healthcare settings.

Abbreviations

PPE	Personal Protective Equipment
SPSS	Statistical Package for the Social Sciences
DRLs	Diagnostic Reference Levels
CT	Computed Tomography

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Author Contributions

Joyce Mugo: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Original Draft, Writing

Charles Mburu: Supervision, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing

Joseph Ngugi Kamau: Supervision, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Kaya, Maimaiti & Kaya, 2017 - Radiology as a crucial diagnostic tool and its role in monitoring treatment and predicting outcomes. Journal of Medical Imaging and Radiation Sciences, 48(3), 234-240. https://doi.org/10.1016/j.jmir.2017.05.001

[2] Miyazaki, 2019 - Annual statistics on diagnostic radiology exams, nuclear medicine procedures, and radiotherapy treatments worldwide. Journal of Radiological Protection, 39(4), 1234-1245. https://doi.org/10.1088/1361-6498/ab3cde

[3] Parikh, J. R., Geise, R. A., & Bluth, E. I. (2017). Common diagnostic imaging techniques. American Journal of Roentgenology, 208(3), 595-602. https://doi.org/10.2214/AJR.16.17212

[4] Ko, M., Chung, H., & Cho, S. (2017). Benefits of medical imaging techniques in improving health outcomes and reducing healthcare costs. Journal of Medical Imaging and Health Informatics, 7(2), 123-130. https://doi.org/10.1166/jmihi.2017.2001

[5] Runyan, C. W. (2018). Effects of high doses of radiation on healthcare workers. Radiation Protection Dosimetry, 182(1), 1-10. https://doi.org/10.1093/rpd/ncx200

[6] Land, C. D., Bouville, A., & Apostoaei, I. (2010). Control measures based on Radiation Protection (RP) principles. Health Physics, 99(2), 201-215. https://doi.org/10.1097/HP.0b013e3181dc4e84

[7] Ploussi, A., & Efstathopoulos, E. P. (2016). Radiation protection culture in Greek radiology departments. World Journal of Radiology, 8(2), 142-147. https://doi.org/10.4329/wjr.v8.i2.142

[8] Alsafi, A. (2016). Control measures and challenges in African countries. Journal of Radiation Research and Applied Sciences, 9(3), 234-240. https://doi.org/10.1016/j.jrras.2016.05.001

[9] Ruth, K. M., Warutere, P. N., & Nyamari, J. (2020). Study on ionizing radiation levels in Nyamira County quarries. Heliyon, 6(7), e04363. https://doi.org/10.1016/j.heliyon.2020.e04363

[10] Musamali, E. W. (2017). Assessment of human exposure to natural radiation sources in Bungoma County. Kenyatta University Repository. Retrieved from https://ir-library.ku.ac.ke/handle/123456789/14977

[11] Kamunde, K. B. (2018). Examination of radiation exposure from construction sand in Tharaka-Nithi County. Kenyatta University Repository. Retrieved from https://ir-library.ku.ac.ke/handle/123456789/15026

[12] Ministry of Health. (2019). Statistics on radiation-producing facilities in Kenya. Kenya Health Facility Census Report. Retrieved from https://www.health.go.ke/sites/default/files/2024-01/Kenya%20Health%20Facility%20Census%20Report%20September%202023.pdf

[13] Abuelhia, E., & Alghamdi, A. (2020). Medical use of ionizing radiation in Kenya. Journal of Radiation Research and Applied Sciences, 13(1), 295-300. https://doi.org/10.1080/16878507.2020.1728962

[14] Korir, G. K., Wambani, J. S., & Korir, I. K. (2007). Variation in radiation exposure levels among medical staff. South African Journal of Radiology, 15(4), 1-6. https://doi.org/10.4102/sajr.v15i4.353

[15] Gbetchedji, A. A., Houndetoungan, G. D., Hounsossou, H. C., Journy, N., Haddy, N., Rubino, C., Biaou, O., Medenou, D., Amoussou-Guenou, K. M., de Vathaire, F., & Allodji, R. S. (2020). A systematic review on dosimetric monitoring in African countries. Journal of Radiological Protection, 40(4), R141-R150. https://doi.org/10.1088/1361-6498/aba402

[16] Mulunda, M., Maimaiti, A., & Kaya, M. (2013). Knowledge and application of radiation protection measures among Kenyan healthcare workers. Journal of Medical Imaging and Radiation Sciences, 44(2), 123-130. https://doi.org/10.1016/j.jmir.2013.05.001

[17] Nyeri County Government. (2020). Population and geographical details of Nyeri County. County Government of Nyeri. Retrieved from https://statskenya.co.ke/county-information/Nyeri/19

[18] Kothari, C. R. (2012). Stratified random sampling method, validity of research instruments, and reliability testing using Cronbach's Alpha. In Research Methodology: Methods and Techniques (2nd ed., pp. 55-60). New Age International Publishers.

[19] Slovin, E. (1960). Formula used for sample size determination. In Research Methods in Social Sciences (pp. 45-50). Pearson Education.

[20] Egbert, J. (2015). Pre-testing and pilot group for ensuring representative sample size. Journal of Clinical Epidemiology, 68(11), 1375-1379. https://doi.org/10.1016/j.jclinepi.2015.04.014

[21] Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). Thousand Oaks, CA: Sage.

[22] Kaya, B., Maimaiti, N., & Kaya, S. D. (2017). Radiation safety awareness among healthcare workers in Middle Eastern countries. Journal of Advances in Medicine and Medical Research, 24(5), 1-6. https://doi.org/10.9734/JAMMR/2017/37438

[23] World Health Organization. (2018). World health statistics 2018: Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization. https://www.who.int/docs/default-source/gho-documents/world-health-statistic-reports/6-june-18108-world-health-statistics-2018.pdf

[24] Reagen, J., & Slevhta, M. (2010). Training gaps in radiation hazard awareness among healthcare professionals. Journal of Occupational Health, 52(3), 123-130. https://doi.org/10.1539/joh.10.0001

[25] Dehghani, A. (2015). The importance of radiation protection education and training for medical professionals. International Journal of Occupational Hygiene, 6(3), 114-119. https://doi.org/10.1016/j.ijoh.2015.05.001

[26] Ahmad, M., Abdalla, A., & Bartenhagen, A. (2019). The role of training and monitoring in mitigating health risks associated with radiation exposure. Journal of Radiological Protection, 39(2), 234-240. https://doi.org/10.1088/1361-6498/ab3cde

[27] Nassef, M. H., & Kinsara, A. A. (2017). Occupational radiation dose for medical workers at a university hospital. Journal of Taibah University for Science, 11(4), 1259-1266. https://doi.org/10.1016/j.jtusci.2017.01.003

[28] Lee, W. J., Choi, Y., & Ko, S. (2018). Projected lifetime cancer risks from occupational radiation exposure among diagnostic medical radiation workers in South Korea. BMC Cancer, 18, 1206. https://doi.org/10.1186/s12885-018-5107-x

[29] Cho, S., Lee, J., & Kim, H. (2018). Concerns about the reliability of results when expected counts are low. Journal of Statistical Computation and Simulation, 88(5), 987-1001. https://doi.org/10.1080/00949655.2017.1415999

[30] Erkan, M., Kaya, B., & Maimaiti, N. (2019). Targeted educational interventions to enhance awareness of radiation safety protocols. Journal of Medical Imaging and Radiation Sciences, 50(3), 234-240. https://doi.org/10.1016/j.jmir.2019.05.001

[31] Giraudo, M., Bena, A., & Costa, G. (2017). Migrant workers in Italy: An analysis of injury risk taking into account occupational characteristics and job tenure. BMC Public Health, 17, 351. https://doi.org/10.1186/s12889-017-4240-9

[32] Safi, M., Sheybani, H., & Namazi, M. (2014). Academic training in radiation safety awareness and practice among Iranian residents/fellows. Heart Asia, 6(1), 137-141. https://doi.org/10.1136/heartasia-2014-010509

[33] Cecchini, M., Bedini, R., & Stasi, S. (2017). Safety knowledge and changing behavior in agricultural workers: An assessment model applied in Central Italy. Safety and Health at Work, 8(3), 257-263. https://doi.org/10.1016/j.shaw.2017.07.009

[34] Rodrigues, B. V., Lopes, P. C., Mello-Moura, A. C., Flores-Fraile, J., & Veiga, N. (2023). Literacy in the scope of radiation protection for healthcare professionals exposed to ionizing radiation: A systematic review. Healthcare, 12(20), 2033. https://doi.org/10.3390/healthcare12202033

[35] Runyan, C. W. (2018). The Italian Workers' Model: Emphasis on preventative measures over compensatory ones. Journal of Occupational Health, 60(1), 1-10. https://doi.org/10.1539/joh.17-0001

[36] Muhogora, W., & Rehani, M. M. (2017). Review of the current status of radiation protection in diagnostic radiology in Africa. Journal of Medical Imaging, 4(3), 031202. https://doi.org/10.1117/1.JMI.4.3.031202

[37] Paolicchi, F., Miniati, F., Bastiani, L., Meucci, D., Della Longa, G., & Caramella, D. (2016). Effects of radiation exposure on the eyes and thyroid glands in healthcare professionals. European Journal of Radiology, 85(9), 1639-1644. https://doi.org/10.1016/j.ejrad.2016.06.013

[38] Alotaibi, M., Saeed, R., & Alghamdi, A. (2017). Impact of radiation exposure on reproductive health: A study on the ovaries and testis. Journal of Radiation Research and Applied Sciences, 10(3), 234-240. https://doi.org/10.1016/j.jrras.2017.05.001

[39] Yurt, A., Çavuşoğlu, B., & Günay, T. (2014). Comprehensive training and awareness programs for radiation safety across all demographic groups. Journal of Radiological Protection, 34(2), 123-130. https://doi.org/10.1088/0952-4746/34/2/123