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Assessment of radiation protection officer training in Bangladesh: A pre–post intervention study

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Abstract

The expanding use of ionizing radiation in medical and industrial applications requires competent radiation safety oversight to minimize occupational and public exposure. Radiation Protection Officer (RPO) play a critical role in implementing regulatory requirements and radiation protection measures. However, evidence evaluating the effectiveness of regulatory training programs for RPO in developing countries, including Bangladesh, remains limited. This study aimed to assess the radiation protection and safety knowledge gained from the training for Radiation Protection Officers organized by Bangladesh Atomic Energy Regulatory Authority (BAERA). A pre–post intervention study was conducted among RPO working in diagnostic radiology facilities across Bangladesh. A total of 54 participants completed a structured two-day training program covering regulatory requirements, radiation hazards, radiation protection, facility design, and operational safety. Knowledge was assessed using a questionnaire survey immediately before and after the training. A paired t-test statistical method was applied to compare pre- and post-training scores. The mean pre-training knowledge score was 19.00 (SD = 5.82), which increased significantly to 40.71 (SD = 11.08) following the training ($t = 10.03$, $p < 0.001$). The overall effect size was very large (Cohen's $d = 2.68$), indicating a strong educational impact. Category-wise analysis demonstrated significant improvements across all domains, with the largest gains observed in regulatory knowledge, followed by radiation protection and radiation hazard domains. The Radiation Protection Officer training program was found highly effective in improving radiation safety knowledge. The substantial learning gains highlight the value of structured regulatory training as a key capacity-building tool for strengthening radiation safety culture and regulatory compliance in Bangladesh.

Keywords: Radiation Protection Training; Radiation Protection Officer; Pre–Post Intervention Study; Radiation Safety Knowledge; Assessment of Training Program

1 Introduction

The application of ionizing radiation has expanded significantly in medical diagnostics, radiotherapy, industrial inspection, research, and nuclear technology. While these applications provide substantial benefits to society, exposure to ionizing radiation carries potential risks to human health and the environment if not properly controlled. Ensuring radiation safety therefore requires the establishment of effective regulatory frameworks and competent personnel responsible for implementing protection measures in radiation workplaces. RPO are designated professionals tasked with supervising radiation safety programs, monitoring occupational exposure, ensuring regulatory compliance. The International Atomic Energy Agency (IAEA) Basic Safety Standards emphasize that facilities using radioactive sources must appoint qualified personnel with appropriate education, training, and experience in radiation protection [1].

The increasing utilization of ionizing radiation in medical and industrial applications necessitates a thorough understanding of its potential hazards and the implementation of effective radiation protection measures [6]. This

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imperative is particularly salient for individuals professionally engaged with ionizing radiation, given that insufficient comprehension of radiation protection principles can precipitate avoidable exposures and detrimental health consequences [7]. Consequently, continuous and updated training programs are crucial to enhance radiation protection knowledge among healthcare workers, especially support staff, and thereby improve radiation safety behaviors and attitudes [8]. The efficacy of such educational interventions in enhancing clinicians' knowledge of radiation protection has been demonstrated, with studies consistently reporting significant increases in participants' understanding post-training [9].

The present study therefore aims to evaluate the impact of a specialized training program by the Bangladesh Atomic Energy Regulatory Authority (BAERA) on the radiation safety knowledge of Radiation Protection Officers in Bangladesh, utilizing a pre- and post-intervention design. This approach allows for a direct assessment of the training program's effectiveness in improving radiation protection knowledge.

2 Literature Review

2.1 Need for Radiation Protection Training

Radiation protection is founded on three fundamental principles: justification of practice, optimization of protection (ALARA), and dose limitation. Effective implementation of these principles requires trained personnel capable of understanding radiation hazards, regulatory requirements, and appropriate control measures [1]. The World Health Organization (WHO) and IAEA have both emphasized that lack of adequate training remains a major contributor to unsafe radiation practices in low- and middle-income countries [2].

Training in radiation protection has been recognized as an essential component of national radiation safety systems. IAEA Safety Guide RS-G-1.4 highlights that RPO must receive formal training covering radiation physics, biological effects, monitoring techniques, emergency preparedness, and regulatory compliance [3]. Competency-based training ensures that RPO can translate theoretical knowledge into practical safety management in workplaces.

2.2 Effectiveness of Radiation Protection Training

Numerous studies have assessed the impact of radiation safety education using pre–post intervention designs. Effective radiation protection training significantly enhances healthcare workers' knowledge, attitude, and practices concerning radiation safety. Educational interventions consistently lead to increased understanding of radiation protection principles among participants, with studies reporting positive outcomes such as improved safety compliance and a reduction in radiation exposure incidents [11]. Furthermore, the long-term benefits of regular and ongoing education in maintaining safety compliance have been highlighted [11]. It is crucial that training programs are continuous, up-to-date, and comprehensive, particularly for support staff and students. The most effective training combines theoretical knowledge with practical application, as theoretical instruction alone may not ensure knowledge retention over time [12].

Studies indicate that satisfactory awareness of radiation protection is strongly linked to higher educational levels, extensive experience, and consistent attendance at training courses, emphasizing the need for robust educational frameworks and more successful, engaging training for all professionals [13]. These findings confirm that structured education is effective in improving knowledge and promoting safer behavior in radiation workplaces. However, most available studies originate from developed countries or hospital-based settings. Evidence from regulatory training programs in developing nations remains limited.

2.3 Regulatory Contexts

Regulatory authorities worldwide implement training programs for Radiation Protection Officer as part of licensing and compliance requirements. The IAEA “Train-the-Trainers” program supports national regulators in building sustainable education frameworks for radiation protection professionals [4]. Evaluations of such programs in several Asian and African countries have demonstrated improved national capacity in regulatory oversight and radiation safety enforcement [5].

Training evaluation models commonly use knowledge-based assessments as primary outcome measures. According to Kirkpatrick’s evaluation framework, learning outcomes measured through pre–post testing provide direct evidence of training effectiveness [10]. This approach has been widely applied in radiation protection education research.

2.4 Bangladesh Contexts

Bangladesh has experienced rapid expansion of radiation use in medical imaging, radiotherapy, and industrial non-destructive testing. BAERA oversees licensing, inspection, and training activities to ensure compliance with national safety standards. The Nuclear Safety and Radiation Control Rules (1997) and BAER Act (2012) require facilities using radioactive sources to appoint trained RPO [6]. BAERA conducts regular training courses for RPO, covering regulatory requirements, radiation monitoring, protection principles, and emergency response. However, published literature evaluating the effectiveness of these training programs is scarce. Without systematic evaluation, it is difficult to identify strengths, gaps, and opportunities for improvement in national radiation protection education. Therefore, assessing the impact of BAERA RPO training program through a pre–post intervention study is essential to generate evidence-based recommendations for enhancing training quality and strengthening radiation safety governance in Bangladesh.

3 Methodology

3.1 Study Design and Setting

A pre–post intervention study design was employed to assess the effectiveness of the BAERA Radiation Protection Officer Training Program on improving radiation safety knowledge among Radiation Protection Officer working in radiology centers in Bangladesh. The study compared participated RPOs knowledge scores before and after completion of the structured BAERA training intervention, without the inclusion of a separate control group.

The study was conducted across multiple diagnostic radiology centers registered under BAERA. The training was delivered at the premises of BAERA. Data collection was carried out over a four-month period, from February to May of the year 2025, encompassing pre-training assessment, training delivery, and post-training evaluation. The study population consisted of RPO working in diagnostic radiology facilities across Bangladesh. Participants who enrolled in the BAERA Radiation Protection Training Program during the study period were included. A census sampling approach was applied, where all eligible trainees during the study period were invited to participate. Participants who were attended before were excluded from the study.

The BAERA RPO training program is a structured regulatory training course designed to enhance competency in radiation safety and regulatory compliance. The training curriculum covered:

- Legal basis for control of x-ray facilities
- Room design and shielding
- X-ray generating equipment and its general safety
- Radiation monitoring
- Licensing procedure for diagnostic x-ray facilities
- Radiation hazard, quantities and units
- Radiation detection and measurement
- Biological effects of ionizing radiation
- Medical exposure control
- Duties and responsibilities of RPO
- Practical sessions

The training included lectures, interactive discussions, practical demonstrations, and case-based learning sessions, delivered by experts. A two-day training is organized that comprises 11 technical lectures, each one hour in duration.

3.2 Data Collection

A structured self-administered questionnaire was developed to assess participants' knowledge of radiation safety and regulatory compliance. The question was developed strategically to ensure that it covered all aspects of radiation protection and safety relevant to radiation protection officers. The questionnaire consisted of 14 multiple-choice questions, covering key domains:

- Regulation
- Radiation hazards
- Radiation protection
- Facility design and operation

Each correct response was awarded one point, giving a maximum possible score of 14. Higher scores indicated better knowledge of radiation protection and regulatory requirements. Participants completed the questionnaire immediately before commencement of the training program and immediately after completion of the training program. Both assessments used identical questionnaires to allow direct comparison of knowledge improvement attributable to the training intervention.

3.3 Data Analysis

Collected data were coded and entered into statistical software Excel. Descriptive statistics were used to summarize participants' demographic characteristics and knowledge scores. Continuous variables (scores) were expressed as mean ± standard deviation and categorical variables were presented as percentages.

To evaluate the effectiveness of the training program a paired sample t-test was applied to compare pre-training and post-training mean scores. A p-value of <0.05 was considered statistically significant. Percentage improvement in knowledge scores was calculated to quantify training impact. Graphical presentations such as bar charts and plots were used to illustrate changes in knowledge scores before and after training.

4 Results and Discussion

The questionnaire was distributed among a total of 71 participants. However 54 participants took part in the study generating a response rate of 76.1%. The participants were employed RPO working at private radiology centers and were licensed to practice diagnostic radiography in Bangladesh. The total number of female participants was 6 (11.1%), while 48 (88.9%) were male RPO. The ages of RPO ranged between 18–61 years old, with a mean of 27±8.2 years. 51.8% participants hold a Diploma in Medical Technology, while 18.5% hold BSc degree, 7.4% hold Master's degree and remaining 22.2% holds up to higher secondary education certificates. Experience level varied, with a significant no of participants (64.8%) having less than one year of professional experience. Other experience categories included 2-5 years (25.9%) and more than 5 years (9.2%).

Table 1 Accumulated score of four categories of questions

Question No.	Category	Pre training score	Post training score
1	Regulation	15	37
2	Regulation	23	49
3	Regulation	24	53
4	Radiation hazard	32	54
5	Radiation hazard	14	39
6	Radiation hazard	19	25
7	Radiation hazard	20	43
8	Radiation protection	13	41
9	Radiation protection	17	25
10	Radiation protection	15	43
11	Radiation protection	27	54
12	Facility design and operation	11	19
13	Facility design and operation	17	42
14	Facility design and operation	19	46

A structured 14-item questionnaire was designed to evaluate participated RPOs knowledge of radiation safety and protection. The questions were organized into four thematic categories representing the core competencies required of a Radiation Protection Officer for the safe management of occupational practices. Each correct answer was assigned one point, and total scores were calculated by summing the number of correct responses. The pre- and post-training

assessment results are summarized in Table 1. The distribution of participants' score ranges before and after the training intervention is presented in Figure 2. Pre-training scores ranged from 2 to 7, whereas post-training scores showed a substantial improvement, ranging from 8 to 13.

The effectiveness of the training program was evaluated using a paired pre–post knowledge assessment. The mean pre-training score was 19.00 (SD = 5.82), which increased to 40.71 (SD = 11.08) following the training intervention. A paired-sample t-test demonstrated a highly significant improvement in knowledge scores (t = 10.03, p < 0.001). The magnitude of the training effect was very large (Cohen's d = 2.68), indicating both statistical and practical significance of the intervention.

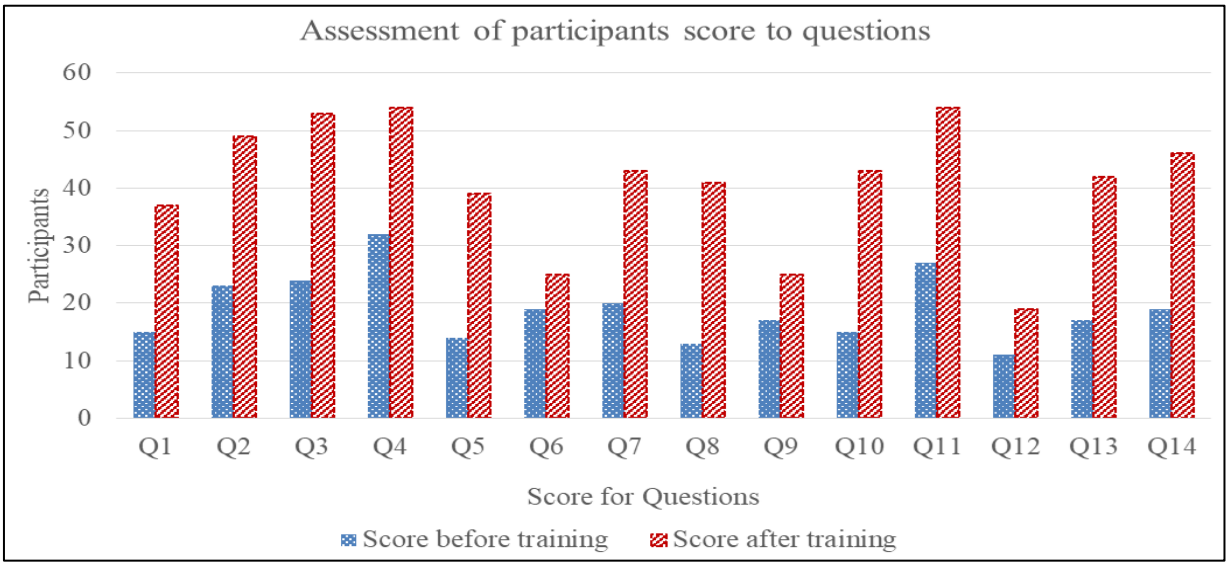

Figure 1 Assessment of participants' pre and post training score

Category-wise analysis revealed consistent improvements across all thematic domains. The regulation domain showed the highest learning gain (Pre: 20.67 ± 4.93; Post: 46.33 ± 8.33; t = 12.66, p = 0.006, d = 7.31), followed by radiation protection (Pre: 18.00 ± 6.22; Post: 40.75 ± 11.95; t = 4.62, p = 0.019, d = 2.31) and radiation hazard (Pre: 21.25 ± 7.63; Post: 40.25 ± 11.98; t = 4.34, p = 0.023, d = 2.17). Facility design and operation also demonstrated substantial improvement (Pre: 15.67 ± 4.16; Post: 35.67 ± 14.57; d = 1.92), showing a strong educational effect despite marginal statistical significance due to limited subdomain sample size.

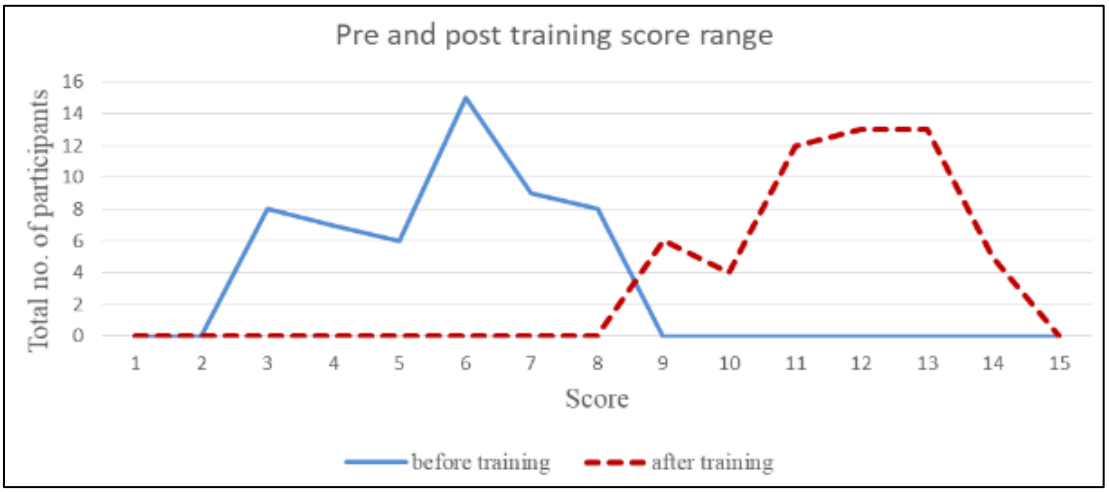

Figure 2 Assessment of pre and post training score range

The findings of this study demonstrate that the training program produced a statistically significant and educationally meaningful improvement in participated RPOs' radiation safety knowledge. The overall effect size indicates that the training was not only effective in increasing test scores but also in achieving deep learning outcomes with practical relevance to radiation safety practice.

Table 2 Category-wise statistics

Category	Pre Mean	Pre SD	Post Mean	Post SD	t-value	p-value	Effect Size (Cohen's d)	Interpretation
Regulation	20.67	4.93	46.33	8.33	12.66	0.006	7.31	Extremely large effect
Radiation Hazard	21.25	7.63	40.25	11.98	4.34	0.023	2.17	Very large effect
Radiation Protection	18.00	6.22	40.75	11.95	4.62	0.019	2.31	Very large effect
Facility Design & Operation	15.67	4.16	35.67	14.57	3.32	0.080	1.92	Large effect

Mean pre training score = 19.00; Mean post training score = 40.71; Pre training Standard Deviation (SD) = 5.82; Post training Standard Deviation (SD) = 11.08

The strongest improvements were observed in the regulation domain, suggesting that structured training is particularly effective in strengthening regulatory understanding, compliance awareness, and procedural knowledge. This is critical for Radiation Protection Officers, whose professional responsibilities depend heavily on regulatory literacy and compliance behavior. Significant gains in radiation hazard and radiation protection domains further indicate improved risk perception, hazard recognition, and protective practice awareness, which are core components of radiation safety culture.

Improvements in facility design and operation knowledge, although statistically less robust due to limited subdomain data, still demonstrated a large effect size, reflecting meaningful conceptual learning. This suggests that the training program successfully addressed both theoretical knowledge and applied operational principles.

Overall, the results support the training program as a highly effective capacity-building intervention. The consistency of improvement across domains indicates that the program contributes to strengthening institutional radiation safety culture, regulatory compliance, and professional competency. These findings support the continued implementation, expansion, and periodic evaluation of structured radiation protection training programs as a strategic tool for national radiation safety strengthening.

5 Conclusion

This study demonstrates that the training program was highly effective in significantly enhancing Radiation Protection Officers' knowledge, as evidenced by a substantial increase in post-training assessment scores compared with pre-training levels. The statistically significant improvement and large effect size indicate that the training intervention achieved both strong educational and practical impact across the participant group. The consistency of learning gains suggests that the program successfully addressed baseline knowledge gaps among trainees with varying levels of prior understanding. Overall, the findings support the value of structured and targeted training as an effective approach for capacity building and underscore its importance in strengthening professional competence and promoting improved safety and compliance practices.

Limitations

The study has several limitations, including the lack of a control group, which makes it challenging to attribute observed improvements solely to the training. The study also evaluated participants immediately after the intervention, preventing an assessment of long-term knowledge retention. Reliance on a self-administered questionnaire measured theoretical knowledge rather than practical application. The small sample size and participants from a single program limit the broader applicability of the findings. Future studies should address a large sample size, control group and longer follow up to assess long-term knowledge retention and the training outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that the training program evaluated in this study was conducted by the regulatory authority; however, this did not influence the study design, data analysis, interpretation of results, or manuscript preparation.

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