Journal of Radiological
Protection

PAPER • **OPEN ACCESS**

Portuguese translation, validity and psychometric evaluation of the healthcare professional knowledge of radiation protection scale

To cite this article: Belinda Rodrigues *et al* 2026 *J. Radiol. Prot.* **46** 021523

IOP Publishing J. Radiol. Prot. 46 (2026) 021523 https://doi.org/10.1088/1361-6498/ae6f26

Journal of Radiological Protection

OPEN ACCESS

RECEIVED
7 February 2026

REVISED
18 April 2026

ACCEPTED FOR PUBLICATION
18 May 2026

PUBLISHED
28 May 2026

PAPER

Portuguese translation, validity and psychometric evaluation of the healthcare professional knowledge of radiation protection scale

Belinda Rodrigues[1], Pedro Lopes[2,3], Cláudia Machado[4], Javier Flores-Fraile[1] and Nélio Veiga[2,3,*]

[1] Department of Surgery, University of Salamanca, 37008 Salamanca, Spain
[2] Center for Interdisciplinary Research in Health (CIIS) Universidade Católica Portuguesa, 3504-505 Viseu, Portugal
[3] Faculty of Dental Medicine, Universidade Católica Portuguesa, 3504-505 Viseu, Portugal
[4] Diagnostic and Interventional Imaging Clinic, Santo António Local Health Unit, Porto, Portugal
[*] Author to whom any correspondence should be addressed.

E-mail: nveiga@ucp.pt

Keywords: HPKRP, healthcare knowledge, radiation protection

Supplementary material for this article is available online

Abstract

Objectives. This study aimed to validate the Portuguese version of the healthcare professional knowledge of radiation protection (HPKRP) scale to assess knowledge of radiation protection among healthcare workers exposed to ionizing radiation. The increasing use of radiation in medicine raises concerns about potential side effects, not only for patients but also for professionals operating the equipment. Appropriate and well-constructed instruments are essential to generate structured and interpretable findings and quantifiable outcomes that support improvements in knowledge, attitudes, and practices. *Methods.* A descriptive correlational cross-sectional study was conducted electronically using a Google Forms survey between March 2025 and July 2025. Participants included nurses, doctors, dentists, and radiographers who use a personal dosimeter. The Portuguese version of the HPKRP was developed using translation and back-translation procedures, followed by statistical validation. Internal consistency, item–total correlations, and regression analyses were performed using IBM SPSS (version 30). *Results.* A total of 247 valid responses were analysed. The scale demonstrated very high internal consistency (Cronbach's alpha = 0.983). Item-total correlations ranged from 0.568 to 0.890, confirming strong internal consistency. Radiographers reported the highest perceived knowledge, while nurses scored lowest. Knowledge gaps were identified particularly in areas related to radiation physics (formulas and units of measurement) and reporting of adverse events. Training in radiation protection was significantly associated with higher scores ($p < 0.001$). *Conclusions.* The Portuguese version of the HPKRP scale demonstrates high internal consistency and provides preliminary evidence of reliability for assessing healthcare professionals' self-perceived knowledge of radiation protection. However, as a subjective measure, it does not reflect objective knowledge or clinical competence and should be interpreted with caution. The instrument may be useful for identifying perceived knowledge gaps and supporting educational strategies when used in combination with objective assessment methods.

List of abbreviations

HPKRP-PT	Healthcare professional knowledge of radiation protection scale
PT	Portugal
RP	Radiation protection
IR	Ionizing radiation

NCRPs	National council on radiation protection and measurements
ICRPs	International commission on radiological units
ALARA	As low as reasonably achieved
MOOCs	Massive open online courses

1. Background

Health literacy includes both personal and organizational dimensions, with healthcare workers playing a key role in its development. The HPKRP scale specifically measures self-perceived knowledge of radiation protection, rather than general or organizational health literacy. It should therefore be interpreted as assessing domain-specific professional knowledge and perceived competency, while remaining conceptually aligned with domain-specific health literacy [1].

The use of ionizing radiation in medicine has increased, and concerns about side effects have also grown. The ICRUs and the NCRPs have over time proposed measurement units for radiation and radioactivity, recommended standardized procedures, and provided essential physical data for application [2]. The cumulative radiation that patients and medical staff receive over a lifetime has risen with the expanding use of ionizing radiation in medicine. Its application in cardiovascular interventions continues to grow [3].

In paediatric patients, the risk of radiation-related late effects is higher because sensitivity to radiation is greater in childhood than in adulthood; therefore, potential late effects must be carefully assessed [4].

Also, in cancer field, ionizing radiation is routinely applied across a wide range of diagnostic and therapeutic procedures, making radiation protection a critical concern [5].

Despite its undeniable benefits, ionizing radiation also poses significant hazards, affecting not only patients but also equipment operators and other healthcare professionals [6].

Controlling radiation exposure by developing protective measures and optimizing procedures is essential [2]. Exposure to ionizing radiation is primarily associated with an increased risk of cancer, and, at higher or prolonged exposure levels, with deterministic effects such as cataracts. The magnitude of risk depends on dose and duration of exposure [5]. In addition to government and international regulations, strict criteria define when ionizing radiation should be used. These include justification of medical exposure benefits and risks, optimization of patient dose to the lowest reasonably achievable level that still provides sufficient image quality for the intended purpose, and compliance with legislative dose limits for healthcare workers and the public [7, 8].

Radiation ward staff should be well informed about radiation protection principles. They should be able to apply safety measures during radiation exposure to safeguard their own health and that of their patients [5]. The purpose of radiation protection is to limit exposure to radiation so that the risk associated with ionizing rays are reduced as much as possible [9]. Applying the ALARAs principle is demanding, the principle that while the primary objective of radiography is to produce images that aid diagnosis, the radiation dose to the patient must be minimized [8, 10].

Concerning knowledge of radiation protection, several studies have been conducted to assess the extent to which members of the medical team know about radiation protection issues and tools to assess knowledge [11–13]. In-depth analysis is required during students̀ training to better evaluate the state of education in radiation protection, identify weakness, and address non-cognitive gaps in curricula to reduce errors. These same shortcomings must be identified during professional practice and corrected through continuous training [11].

Schoderus-Salo *et al* [7] has developed and validated an English psychometric scale to assess the knowledge of Radiation Protection (HPKRP) scale [7], which focuses on radiation physics, principles of radiation use, radiation protection, and guidelines for the safe application of ionizing radiation.

Therefore, it is essential to have reliable and valid tools that increase the objectivity of findings and provide quantifiable outcomes to improve communication and practice. This study aimed to validate a psychometric questionnaire for assessing compliance with radiation protection among Portuguese healthcare workers [11, 12].

2. Methods

2.1. Study design and participants

This was a descriptive correlational study conducted between March 2025 and July 2025. Data were collected electronically via Google Forms. Participants were recruited through institutional mailing lists, professional networks, and hospital departments, targeting healthcare professionals working in clinical settings involving exposure to ionizing radiation and who are required to use personal dosimeters as part of routine occupational safety procedures. The inclusion criteria were healthcare professionals—nurses, doctors, dentists, and radiographers—who regularly use a personal dosimeter. Residents, students, and other healthcare professionals were excluded. A total of 408 invitations for study participation were sent from which 268 responses were obtained; 21 incomplete questionnaires were excluded, resulting in 247 valid responses, corresponding to a response rate of 60.5%.

2.2. Instrument

The HPKRP scale is a psychometric instrument developed to assess literacy in radiation protection among healthcare workers [7]. It comprises three sub-dimensions: (i) radiation physics and biology, (ii) radiation protection regulations and clinical use, and (iii) radiation safety at work, for a total of 33 items. Each item is scored on a 10-point Likert scale (1 = no knowledge to 10 = full knowledge), with higher scores indicating greater perceived knowledge.

The Portuguese version of the HPKRP was developed to ensure accurate comprehension and reduce potential response bias among healthcare professionals, for whom the use of validated instruments in the native language is essential. Additionally, cultural and contextual factors—such as differences in clinical practice, training pathways, and national radiological protection regulations—may influence how items are interpreted, reinforcing the need for cross-cultural adaptation. Accordingly, a standardized translation and back-translation procedure was followed to ensure semantic, conceptual, and measurement equivalence, in line with established methodological recommendations. Two bilingual translators independently translated the original scale into Portuguese. An expert panel, including a native English-speaking health professional, reviewed the translations for semantic and cultural equivalence. A professional translator performed the back translation, which was compared with the original version to verify conceptual accuracy. Final adjustments were made to ensure terminological precision.

2.3. Data collection

Participants were invited electronically to complete the survey using Google Forms. Demographic information included age, sex, professional group, years of professional experience, and training in radiation protection. Completion of the questionnaire required approximately 15 min.

2.4. Statistical analysis

Data were analysed using IBM-SPSS version 30. Descriptive statistics were calculated for demographic and scale variables. Reliability was assessed using Cronbach's alpha, and item-total correlations were computed. For inferential analyses, a significance level of $\alpha = 0.05$ (95%CI) was applied; null hypotheses were rejected whenever $p < 0.05$ [14].

2.5. Ethical considerations

All procedures complied with the ethical principles of the 1964 Helsinki Declaration and its later amendments. The study was approved by the Health Ethics Committee of the Universidade Católica Portuguesa on the 26th of February of 2025 (Approval No. 65). Written informed consent was obtained from all participants prior to data collection.

3. Results

A total of 247 valid responses were analysed. The results are presented in four parts: (i) sociodemographic characteristics, (ii) psychometric properties of the Portuguese HPKRP scale, (iii) distribution of knowledge scores, and (iv) group comparisons and predictors of radiation protection knowledge.

For the psychometric analyses, a minimum of five participants per scale item was considered, with an ideal ratio of ten participants per item [15].

3.1. Sociodemographic data

Of the 247 participants included in the study (table 1), the majority were female (73.3%) and most between 36 and 50 years of age (57.9%). Radiographers represented the largest professional group

Table 1. Demographic data.

Variable	Total participants ($n = 247$)
Gender (%)	
Female	181 (73.3%)
Male	66 (26.7%)
Age (years)	
Under 35 years	46 (18.6%)
Between 36 to 50 years	143 (57.9%)
Over 50 years	58 (23.5%)
Professional Group (%)	
Radiographer	103 (41.7%)
Nurse	63 (25.5%)
Dentist	44 (17.8%)
Doctors	37 (15.0%)
Years of experience (years)	
Until 15 years	142 (57.5%)
Between 16 to 30 years	85 (34.4%)
Over 30 years	20 (8.1%)
Training in radiation protection (%)	
No	186 (75.3%)
Yes	61 (24.7%)

(41.7%), followed by nurses (25.5%), dentists (17.8%), and doctors (15.0%). More than half of the participants (57.5%) reported up to 15 years of professional experience, while only 8.1% had over 30 years of experience. With respect to specific training in radiation protection, fewer than one quarter (24.7%) of participants indicated having received formal education in this area.

3.2. Psychometric properties HPKRP-PT

The Portuguese HPKRP scale consists of 33 items rated on a 10-point Likert scale, where 1 corresponds to no knowledge and 10 to full knowledge. Designed as a unidimensional instrument, all items assess the same construct, and the total score is calculated by summing the item responses, yielding a possible range from 33 to 330 points.

To evaluate the instrument's measurement properties, internal consistency was examined. Reliability refers to the degree of consistency with which a construct is measured, and the most widely applied indicator of internal consistency is Cronbach's alpha (α). According to Nunnally *et al* [14], values above 0.70 are considered acceptable, whereas values below 0.50 are deemed inadequate.

As shown in table 2, Cronbach's α reached 0.983, a level that could not be improved by removal of any single item. Item-total correlations were also strong and positive, averaging $r = 0.796$ (range: 0.568–0.890). These results suggest that the items are consistently related to the overall construct, although the high level of internal consistency may also reflect overlap between items.

Taken together, these findings suggest that the Portuguese HPKRP scale demonstrates strong internal consistency for assessing healthcare professionals' self-perceived knowledge of radiation protection. However, the very high Cronbach's alpha may reflect overlap between items, and results should therefore be interpreted with caution [16].

3.3. Descriptive statistics of the scale

Descriptive statistics for the HPKRP-PT (table 3) indicated a mean total score of 215.27 (SD = 80.0; median = 223), with observed values ranging from 39 to 330 (figure 1). This distribution closely approximates the theoretical range of the scale (33–330), suggesting that the instrument adequately captures the variability in participants' knowledge levels. In addition, skewness (−0.250) and kurtosis (−1.151) values were within the acceptable interval [−1.5, 1.5], indicating no significant deviations from normality [17].

Table 2. Scale reliability.

Item HPKRP—PT	Item-total correlation	Alpha if item deleted
Q1	0.873	0.982
Q2	0.863	0.982
Q3	0.857	0.982
Q4	0.872	0.982
Q5	0.825	0.982
Q6	0.863	0.982
Q7	0.854	0.982
Q8	0.826	0.982
Q9	0.851	0.982
Q10	0.764	0.983
Q11	0.834	0.982
Q12	0.848	0.982
Q13	0.754	0.983
Q14	0.802	0.983
Q15	0.718	0.983
Q16	0.832	0.982
Q17	0.689	0.983
Q18	0.707	0.983
Q19	0.785	0.983
Q20	0.890	0.982
Q21	0.842	0.982
Q22	0.848	0.982
Q23	0.854	0.982
Q24	0.742	0.983
Q25	0.750	0.983
Q26	0.815	0.982
Q27	0.791	0.983
Q28	0.745	0.983
Q29	0.808	0.982
Q30	0.568	0.983
Q31	0.604	0.983
Q32	0.738	0.983
Q33	0.849	0.982
Scale	0.796 (average score)	0.983 (global)

Table 3. Descriptive statistics.

Scale	*M* (DP)	Median	Min–Max	Asymmetry	Kurtosis
HPKRP—PT	215.27 (80.0)	223	39-330	−0.250	−1.151

3.4. Descriptive analysis of knowledge scores

To provide a qualitative classification of healthcare professional's knowledge of radiation protection, the theoretical score range of the scale was divided into three equally sized intervals.

Table 4 presents the qualitative classification of each interval, as well as the respective absolute and relative frequencies of participants within them. According to this classification grid, the most prevalent category was *High* (46.2%). However, significant relative frequencies were found at both *Moderate* (32.8%) and *Low* (21.1%) levels of knowledge, suggesting a pressing need for training for these healthcare professionals.

At the item level, the highest knowledge scores were observed for practical aspects of radiation protection. Participants reported strong knowledge of taking special precautions when working with colleagues in a controlled area (Q15) and of using personal protective equipment against ionizing radiation (Q13), both with a median score of 9. In contrast, knowledge was weakest in radiation physics: only 29.6% of participants demonstrated high knowledge of formulas and units of measurement (Q9; median = 5). From an operational perspective, reporting practices also revealed substantial gaps, as only 34.0% of respondents indicated knowing how to report an adverse event (Q30), and the same proportion understood when such reporting should occur (Q31) (table 5).

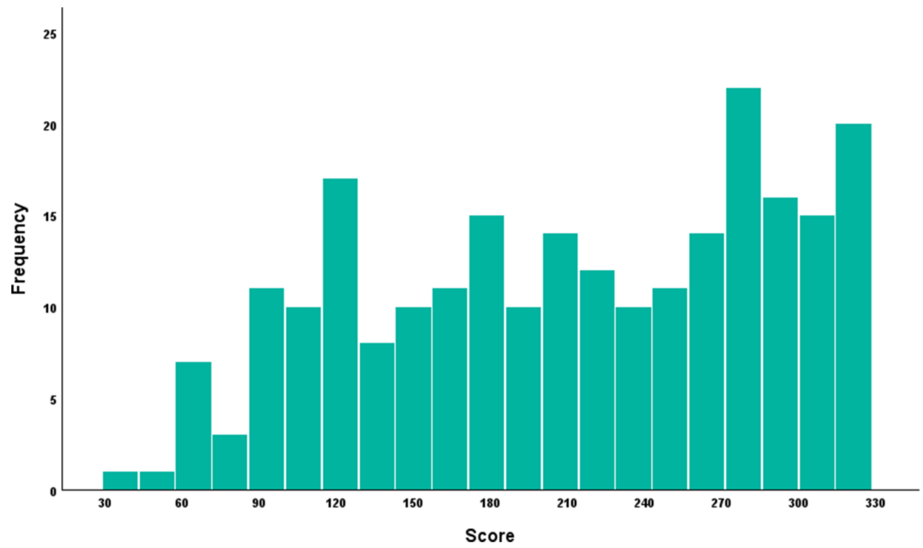

Figure 1. Histogram of distribution total score of the scale.

Table 4. Level of knowledge classification grid.

Scale range	Knowledge	*N*	%
From 33 to 132	Low	52	21.1%
From 133 to 231	Moderate	81	32.8%
From 232 to 330	High	114	46.2%

3.5. Inferential statistics

To study the potential associations between the total HPKRP- PT score and key independent variables (sex, professional group, years of experience, and training in radiation protection), both bivariate tests and multiple linear regression analyses were performed. As this is an observational study, the associations identified cannot be interpreted as causal relationships. Rather, the analyses reflect direct statistical associations between the dependent variable (knowledge score) and each predictor, without accounting for possible interactions with unmeasured factors.

Scale vs. Gender

As shown in Table 6, male participants scored significantly higher than female participants ($M = 233.0$ vs 208.8; $p = 0.024$), although the effect size was small (Cohen's $d = 0.305$). However, gender distribution was not uniform across professional groups (table 7). For example, most nurses were female (92.1%), while most doctors were male (59.5%). This overlap suggests an interaction between gender and professional category (figure 2).

However, as table 7 shows, the gender distribution is not uniform among the various professional groups which leads to an interaction between sex/professional group and the scale score.

Scale vs. Professional group

Analyses of variance revealed significant differences among professional groups ($F = 59.18$; $p < 0.001$) (table 8). Three clusters were identified: nurses had the lowest mean scores ($M = 144.9$; Cluster A), doctors and dentists had intermediate scores ($M = 185.8$ and 210.3, respectively; Cluster B), and radiographers obtained the highest scores ($M = 271.0$; Cluster C) (figure 3).

Scale vs professional experience

As shown in table 9, ANOVA revealed a statistically significant effect of professional experience on knowledge scores ($p < 0.001$). Two clusters were identified. Professionals with $\leqslant$15 years of experience reported significantly lower levels of perceived knowledge ($M = 190.44$; Cluster A). In contrast, those with 16–30 years of experience ($M = 244.93$) and those with >30 years ($M = 265.50$) formed a higher-scoring cluster (Cluster B). Although the difference between the latter two groups was not statistically significant, both demonstrated substantially greater perceived knowledge compared with less experienced professionals (figure 4).

Table 5. Descriptive analysis by item.

Item	*M* (DP)	Median	Min–Max	Knowledge (%)
Q1	6.56 (3.1)	7	1–10	47.4%
Q2	6.57 (3.2)	7	1–10	49.4%
Q3	6.26 (3.3)	7	1–10	45.3%
Q4	6.09 (3.2)	6	1–10	42.9%
Q5	7.21 (2.6)	8	1–10	54.7%
Q6	5.98 (3.1)	6	1–10	39.2%
Q7	5.30 (3.4)	5	1–10	35.2%
Q8	6.40 (3.4)	8	1–10	51.0%
Q9	5.11 (3.3)	5	1–10	29.6%
Q10	6.42 (3.6)	8	1–10	51.4%
Q11	7.25 (2.7)	8	1–10	56.3%
Q12	5.56 (3.3)	5	1–10	37.6%
Q13	8.03 (2.3)	9	1–10	68.1%
Q14	7.16 (2.9)	8	1–10	55.9%
Q15	8.26 (2.2)	9	1–10	72.9%
Q16	5.72 (2.9)	6	1–10	34.4%
Q17	6.86 (3.2)	8	1–10	52.6%
Q18	7.02 (2.8)	8	1–10	55.5%
Q19	7.04 (2.9)	8	1–10	56.7%
Q20	6.76 (3.0)	8	1–10	53.9%
Q21	6.78 (3.0)	8	1–10	51.9%
Q22	5.48 (3.6)	5	1–10	39.7%
Q23	7.15 (2.6)	8	1–10	52.2%
Q24	7.48 (2.5)	8	1–10	59.5%
Q25	6.88 (2.8)	8	1–10	53.4%
Q26	6.93 (2.8)	8	1–10	51.8%
Q27	7.27 (2.6)	8	1–10	56.7%
Q28	6.55 (2.9)	7	1–10	46.9%
Q29	5.57 (3.2)	5	1–10	32.8%
Q30	5.43 (3.3)	5	1–10	34.0%
Q31	5.51 (3.2)	5	1–10	34.0%
Q32	6.45 (2.9)	7	1–10	43.3%
Q33	6.26 (3.1)	7	1–10	43.7%

Table 6. Average scale score by gender.

Variable	Group	Mean (SD)	Difference	*t*	*p* -value	*d* (Cohen)
Gender	Female	208.81 (82.5)	24.19	2.283	0.024	0.305
	Male	233.00 (70.2)				

Table 7. Distribution of genders by professional group.

	Female		Male	
Professional group	*n*	%	*n*	%
Nurse	58	92.1%	5	7.9%
Doctor	15	40.5%	22	59.5%
Dentist	33	75.0%	11	25.0%
Radiographer	75	72.8%	28	27.2%

Scale vs. radiation protection training

As shown in table 10, professionals without radiation protection training scored markedly lower ($M = 193.70$, SD = 75.5) than those who had received such training ($M = 281.05$, SD = 53.1).

The mean difference of 87.35 points was statistically significant ($p < 0.001$) and corresponded to a very large effect size (Cohen's $d = 1.236$), highlighting the substantial impact of formal training on knowledge levels (figure 5).

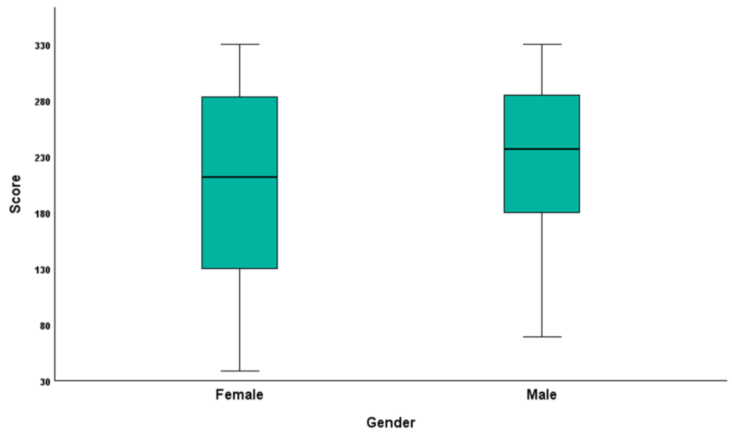

Figure 2. Boxplot of scale vs. gender.

Table 8. Average scale score by professional group.

Professional group	Average	DP	*F* (ANOVA)	*p*-value	Cluster
Nurse	144.94	50.59	59.18	<0.001	A
Doctor	185.84	60.74			B
Dentist	210.27	70.58			B
Radiographers	271.00	62.94			C

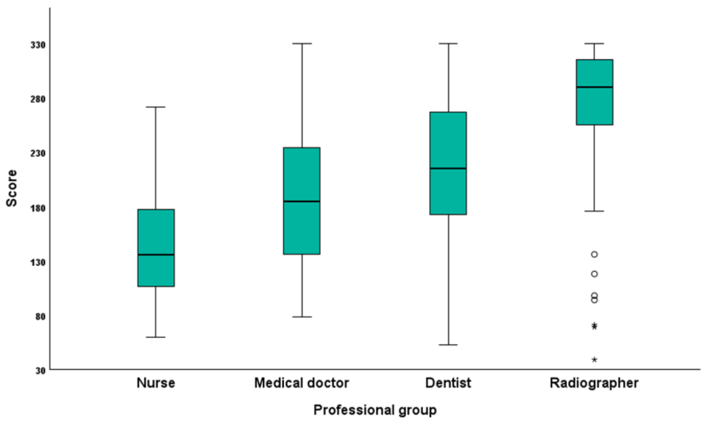

Figure 3. Boxplot of scale vs. professional group.

Table 9. Average scale score by professional experience.

Professional experience	Average	DP	*F* (ANOVA)	*p* -value	Cluster
Up to 15 years old	190.44	76.86	19.06	< 0.001	A
From 16 to 30 years old	244.93	72.96			B
Over 30 years	265.50	65.62			B

3.6. Validity and quality of the final model

The overall model was statistically significant [$F(7.239) = 36.260$, $p < 0.001$], indicating that at least one predictor contributed meaningfully to explaining the variance in scores. The coefficient of determination (R^2) was 0.515, and the adjusted R^2 was 0.501, showing that approximately 51.5% of the variance in knowledge scores was explained by the predictors included in the model. Model assumptions were verified and met. Residuals demonstrated approximate normality (skewness and kurtosis within -1 to $+1$), homoscedasticity (White's test: 34.895, p >0.05), and no evidence of autocorrelation (Durbin-Watson = 1.937). These findings confirm that the model was statistically robust and appropriate for interpretation.

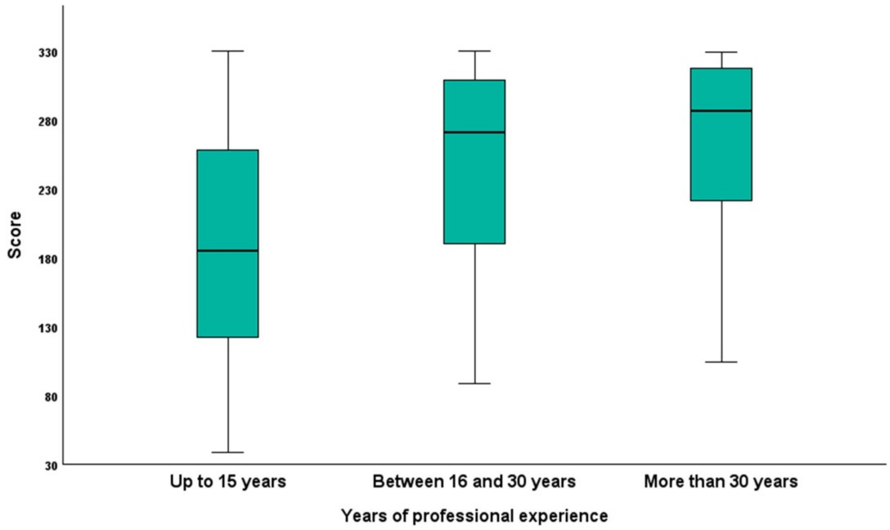

Figure 4. Boxplot of scale vs. professional experience.

Table 10. Average scale score by frequency of radiation protection training.

Variable	Group	Mean (SD)	Difference	t	p -value	d (Cohen)
Training	No	193.70 (75.5)	87.35	9,966	< 0.001	1,236
	Yes	281.05 (53.1)				

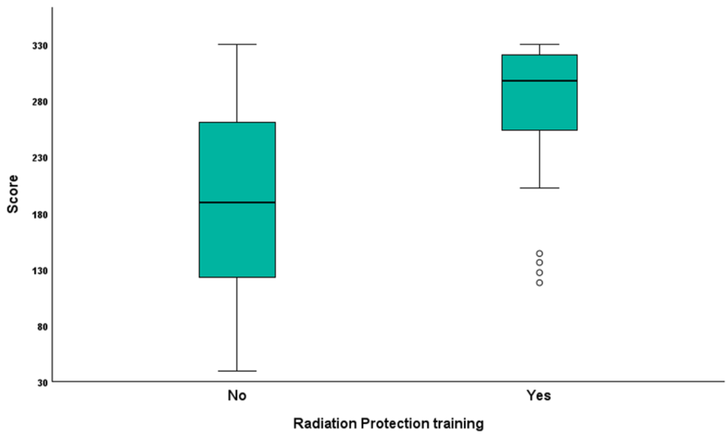

Figure 5. Boxplot of scale score vs. radiation protection training.

As mentioned, 21 responses were excluded from the outset because the scale was not completed. There were no missing values in the fields relevant to the regression model in the responses that were considered, so no imputation was necessary.

3.7. Final model results

The multiple linear regression analysis allowed for the simultaneous assessment of all predictors of radiation protection knowledge. Considering that the relative importance of each predictor is expressed by the standardized coefficient (β), while the absolute impact is reflected in the unstandardized coefficient (B), the results presented in table 11 provide valuable insights. Gender was not significant predictor of knowledge ($p = 0.362$). The adjusted mean difference of 8.10 points in favour of male participants, compared with the unadjusted difference of 21.14 points observed in the bivariate analysis, confirms that the apparent gender effect was largely explained by its interaction with other variables.

In contrast, training in radiation protection emerged as a strong and consistent predictor. Professionals who had received formal training scored, on average, 46.27 points higher on the HPKRP-PT scale than those without such training, with this association being statistically significant ($ß = 0.25$,

Table 11. Results of the linear regression line.

Predictor	Coef. non-standardized B	Coef. Standardized β (beta)	*t*	Value-*p*
(Constant)	130.995		17.211	<.001
Gender = 'Male'	8.099	0.045	0.913	0.362
Training radiation protection = 'yes'	46.265	0.250	5.060	<.001
Professional group = 'Doctor'	39.421	0.176	3.127	0.002
Professional group = 'Dentist'	62.272	0.298	5.514	<.001
Professional group = 'Radiographer'	98.781	0.610	9.945	<.001
Years of professional experience = 'From 16 to 30 years'	28.366	0.169	3.449	<.001
Years of professional experience = 'More than 30 years'	33.777	0.115	2.385	0.018

$p < 0.001$). Professional group also played a decisive role. Using nurses as the reference category, radiographers reported the highest levels of perceived knowledge ($B = 98.78$, $ß = 0.61$, $p < 0.001$), followed by dentists ($B = 62.72$, $ß = 0.30$, $p < 0.001$) and doctors ($B = 39.42$, $ß = 0.18$, $p = 0.002$).

Professional experience further contributed to differences in knowledge levels. Compared with professionals with ⩽15 years of experience, those with more than 30 years reported significantly higher knowledge score ($B = 33.78$, $ß = 0.12$, $p = 0.018$), while participants with 16–30 years of experience also scored higher ($B = 28.37$, $ß = 0.17$, $p < 0.001$). Although the effect sizes were smaller than those of training and professional group, these findings suggest that accumulated clinical experience positively influences awareness of radiation protection.

Taken together, the regression model makes it possible to draw two contrasting participant profiles. A typical participant with a high level of literacy in radiation protection would be a radiographer with a formal training and more than 30 years of professional experience, with an estimated score of 309.8 points out of a maximum of 330. In contrast, a participant with a low level of knowledge would be a nurse with no radiation protection training and ⩽15 years of experience, with an estimated score of 131.1 points.

4. Discussion

The present study aimed to adapt the HPKRP scale for use among Portuguese healthcare professionals and to examine the distribution of radiation protection literacy across professional categories. The Portuguese version (HPKRP-PT) demonstrated very high internal consistency (Cronbach's $\alpha = 0.983$), consistent with the reliability indices reported in both the original Finnish instrument and the Spanish adaptation. Although the Cronbach's alpha was very high (0.983), values of this magnitude may indicate redundancy among items rather than optimal internal consistency. This suggests that some items may be measuring highly overlapping aspects of the construct, and future research should explore potential item reduction strategies [7, 18].

Marked disparities in knowledge levels were observed between professional groups, revealing a pattern consistent with the differentiation of educational curricula and professional exposure to ionizing radiation.

Radiographers achieved the highest mean scores, reflecting their specialized technical training and routine engagement with radiological procedures, while nurses scored significantly lower, exposing substantial gaps in radiation protection literacy among those most frequently positioned close to radiation sources in clinical settings. Doctors and dentists presented intermediate results, confirming that radiation protection knowledge is unevenly distributed across healthcare professions. This trend aligns with international studies that highlight the central role of radiographers in radiation safety and the relative fragility of theoretical knowledge among non-radiologist professionals [19].

Beyond inter-professional variation, recurrent weaknesses were identified across all groups. Deficits were particularly evident in fundamental radiation physics-formulas, units of measurement, and quantitative dose concepts–reflecting limited theoretical literacy. Likewise, widespread uncertainty regarding incident reporting procedures (Q30, Q31) indicates underdeveloped regulatory awareness. In contrast, operational domains such as equipment handling and correct use of personal protective equipment (Q13, Q15) were comparatively strong. This asymmetry–adequate procedural behaviour but fragile conceptual grounding–may compromise the ability to critically appraise exposure risks or to implement dose-optimization strategies grounded in the ALARA principle.

Cross-national comparisons reinforce these conclusions. The Spanish adaptation of the HPKRP, applied to nurses, revealed low literacy levels unrelated to years of professional experience, prompting the authors to recommend the systematic integration of radiation protection content into undergraduate curricula [18].

Similarly Finnish research confirmed insufficient theoretical knowledge and highlighted the need for structured continuous education among nurses [20]. Although methodological differences preclude direct statistical comparison, the convergence of these findings indicate that knowledge deficits in radiation protection constitute a pervasive, transnational phenomenon affecting non-radiologist healthcare workers.

Within this framework, the HPKRP-PT may be considered a useful exploratory tool for assessing self-perceived knowledge and supporting the identification of educational needs.

Evidence from randomized and quasi-experimental studies demonstrates that structured educational initiatives–including MOOCs, hybrid learning, and competency–based training are feasible, well–accepted, and capable of producing measurable improvements in both knowledge and attitudes toward radiation safety [21]. By providing a validated, quantitative metric, the HPKRP-PT enables systematic monitoring of these interventions and supports data-driven educational planning in healthcare institutions.

From an implementation perspective, equivalence testing across administration modes (online, paper-based, and interviewer–assisted) is recommended to ensure measurement invariance and mitigate potential response-mode or sampling bias. In institutional settings, the HPKRP-PT may contribute to educational planning and monitoring of training needs, particularly when used alongside objective assessment methods.

Nevertheless, as the instrument measures self-reported knowledge, it should be triangulated with objective indicators–such as simulated practice assessments, behavioural audits, and dosimetry monitoring–to evaluate whether declared literacy translates into safer practices and measurable dose reduction [22, 23].

From a methodological standpoint, future research should apply multivariable models to control confounding variables such as age, years of experience, and specific training in radiation protection. When parametric assumptions are met, ANOVA with post-hoc corrections or multiple linear regression remains appropriate; in the presence of assumption violations, non-parametric or robust methods should be used. Given the hierarchical structure of healthcare data–professionals nested within departments or hospitals–mixed-effects or multilevel models are preferable for estimating within- and between-group variance and adjusting for intra-cluster correlations. The systematic reporting of effect sizes (Cohen´s d, partial η^2) with confidence intervals is also recommended to enhance transparency, comparability, and reproducibility across validation studies.

At the organizational and policy level, radiation protection literacy should be recognized as a critical dimension of healthcare quality and patient safety. Regulatory bodies, educational institutions, and healthcare organizations are encouraged to incorporate literacy indicators and training benchmarks into accreditation frameworks and professional development plans. Embedding validated tools such as the HPKRP-PT into educational and occupational safety systems can strengthen the *Culture of Radiation Protection Safety*, fostering continuous learning and accountability. By linking individual knowledge assessment with institutional safety outcomes, these initiatives can promote a sustainable culture of radiological protection and contribute to a safer environment for both healthcare professionals and patients.

4.1. Limitations

The HPKRP-PT demonstrated strong internal consistency and proved to be a quick, simple, and useful instrument to assess self-perceived knowledge of radiation protection among Portuguese healthcare professionals. However, it is important to emphasize that this instrument measures perceived knowledge, which may not directly reflect actual competence, behaviour, or compliance in clinical practice. Discrepancies between perceived and actual knowledge are well documented, and therefore the findings should be interpreted with caution. While perceived knowledge may influence professional behaviour, it does not necessarily ensure appropriate clinical application. For this reason, the use of the HPKRP-PT may be strengthened when combined with objective measures of knowledge or practice.

This instrument can be applied in association with other indicators to better assess different professional groups and clinical contexts, providing relevant information for health administrators and policymakers and supporting the development of targeted educational and prevention strategies. Although the tool proved useful among Portuguese healthcare providers, one of the limitations encountered—particularly during data collection—was the response rate. Recruiting participants across all medical specialties exposed to ionizing radiation was challenging, which may have limited the representativeness of the sample and the ability to obtain more profession-specific insights. This limitation may reflect either a limited perceived relevance of the topic or challenges in communicating the scope and importance of the study to potential participants. Nevertheless, the sample size was considered acceptable and comparable to that of the original and Finnish validation studies [7]. The availability of a Portuguese version of the scale represents an important contribution for identifying knowledge gaps and supporting the adaptation of training programs and continuous education initiatives in radiological protection. Further studies in different contexts, ideally combining subjective and objective assessment approaches, are recommended.

5. Conclusion

This study provides preliminary evidence that the Portuguese version of the HPKRP-PT scale demonstrates strong internal consistency for assessing healthcare professionals' self-perceived knowledge of radiation protection.

However, given the subjective nature of the instrument and the potential for item redundancy suggested by the very high internal consistency values, the results should be interpreted with caution. The HPKRP-PT should not be considered a measure of objective knowledge or clinical competence, but rather as a complementary tool to explore perceived literacy in this domain.

In this context, the instrument may be useful for identifying perceived knowledge gaps and informing the design of targeted educational initiatives, particularly when used alongside objective assessment methods.

Future research should focus on further psychometric evaluation, including dimensionality analysis and potential item reduction, as well as on the integration of objective measures of knowledge and practice to better understand the relationship between perceived and actual competence in radiation protection.

Acknowledgment

The authors would like to acknowledge the participants in the study and professionals and responsibles that helped in the data collection.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Supplementary data HPKRP available at https://doi.org/10.1088/1361-6498/ae6f26/data1.

Authors contributions

NV, JFF and PL were responsible for the conceptualization and design of the project. BR and NV were responsible for the data collection. BR, NV and CM were responsible for the statistical analysis and contributions to the various analytical approaches and interpretations of data. JFF, NV, PL and BR drafted the main manuscript and made major contributions to the revising of the manuscript. All authors read and approved the final manuscript submitted.

Funding

This work is financially supported by National Funds through FCT—Fundação para a Ciência e a Tecnologia, I.P., under the Project UID/04279.

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: support was received form Universidade Católica Portuguesa, Portugal, and University of Salamanca, Spain.

Ethics approval and consent to participants

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This research was approved by the Health

Ethics Committee of the Universidade Católica Portuguesa on the 26th of February of 2025 (Approval number 65). Written informed consent was obtained from all participants.

Conflict of interest

The author declares that they have no competing interests.

ORCID iDs

Belinda Rodrigues 0009-0007-2286-428X
Nélio Veiga 0000-0001-6288-0435

References

[1] Pelizzari N, Covolo L, Ceretti E, Fiammenghi C and Gelatti U 2025 Defining, assessing, and implementing organizational health literacy: barriers, facilitators, and tools—a systematic review (BioMed Central Ltd.) (https://doi.org/10.1186/s12913-025-12775-w)
[2] Boice J D, Dauer L, Kase K, Mettler F and Vetter R 2020 Evolution of radiation protection for medical workers (https://doi.org/10.1259/bjr.20200282)
[3] Chen J, Einstein A J, Fazel R, Krumholz H M, Wang Y, Ross J S, Ting H H, Shah N D, Nasir K and Nallamothu B K 2010 Cumulative exposure to ionizing radiation from diagnostic and therapeutic cardiac imaging procedures: a population-based analysis *J. Am. Coll. Cardiol.* **56** 702–11
[4] Afroz S *et al* 2024 Doses from ionising radiation in paediatric cardiac catheterisations in Norway 1975–2021 *J. Radiol. Prot.* **44** 041513
[5] Alshowiman S S 2023 Principles of radiation protection for patients and medical staff *Biomed. J. Sci. Tech. Res.* **54** 45700–8
[6] Talapko J *et al* 2024 Health effects of ionizing radiation on the human body (Multidisciplinary Digital Publishing Institute (MDPI)) (https://doi.org/10.3390/medicina60040653)
[7] Schroderus-Salo T, Hirvonen L, Henner A, Ahonen S, Kääriäinen M, Miettunen J and Mikkonen K 2019 Development and validation of a psychometric scale for assessing healthcare professionals' knowledge in radiation protection *Radiography* **25** 136–42
[8] Rowantree S A and Currie C 2024 Orthopaedic surgeons' knowledge and practice of radiation safety when using fluoroscopy during procedures: a narrative review (W.B. Saunders Ltd.) (https://doi.org/10.1016/j.radi.2023.11.017)
[9] Alotaibi A and Muhyi N 2019 Assessing the radiation protection knowledge among non-radiologists *Int. J. Med.Dev. Countries* **3** 159–62
[10] Hamid M A *et al* 2025 Radiation in the orthopedic operating room: what we know, what we do, and what needs attention *Cureus* **17** e90911
[11] Elzaki M *et al* 2025 Knowledge and comprehension of radiation protection among radiography professionals and interns in western Saudi Arabia *J. Radiat. Res. Appl. Sci.* **18** 101243
[12] Elmorabit N, Obtel M, Azougagh M, Marrakchi A and Ennibi O K 2025 Development and validation of a questionnaire on radiation protection knowledge, attitudes, and practices among Moroccan dentists *J. Appl. Clin. Med. Phys.* **26** e14555
[13] Ramírez L B, Ruiz-Imbert A C, Cascante-Sequeira D, Saballos P O and Rivas A H 2023 Development and validation of a questionnaire on radiation protection in dentistry *Odovtos-Int. J. Dent. Sci.* **25** 419–30
[14] Nunnally J C *et al* 1976 *Psychometric Theory* 3rd edn (McGraw-Hill)
[15] Hair J F, Gabriel M L D S, da Silva D and Junior S B 2019 Development and validation of attitudes measurement scales: fundamental and practical aspects *RAUSP Manag. J.* **54** 490–507
[16] Cronbach L J Coefficient alpha and the internal structure of tests* (https://doi.org/10.1007/BF02310555)
[17] Marôco J 2021 *Análise Estatística com o SPSS Statistics* 3rd edn (Report Number, Lda.)
[18] Llurda-Almuzara L, Lubián R O, Pérez De Gracia D, Pérez-Bellmunt A, Schroderus-Salo T and Tomás Sábado J 2020 Spanish translation and psychometric evaluation of the healthcare professional knowledge of radiation protection scale *J. Radiol. Prot.* **40** 740–52
[19] Paulo G 2020 Radiographer research in radiation protection: national and European perspectives *Radiography* **26** S42–S44
[20] Hirvonen L, Schroderus-Salo T, Henner A, Ahonen S, Kääriäinen M, Miettunen J and Mikkonen K 2019 Nurses' knowledge of radiation protection: a cross-sectional study *Radiography* **25** e108–12
[21] Soenens G *et al* 2024 Development, feasibility, and knowledge impact of a massive open online course on radiation safety: a multicentre prospective cohort study *Eur. J. Vasc. Endovasc. Surg.* **67** 838–46
[22] Hankin R A and Jones S P 2020 The impact of educational interventions on clinicians' knowledge of radiation protection: an integrative review (W.B. Saunders Ltd.) (https://doi.org/10.1016/j.radi.2020.01.008)
[23] Korsah S *et al* 2025 Attitude of medical radiation professionals towards radiation protection principles and practices and strategies for improvement: a scoping review (Elsevier Inc.) (https://doi.org/10.1016/j.jmir.2025.101893)