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Review Article

Worker's exposure to radiation in fluoroscopy, assessing and instruments: A systematic literature review

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ABSTRACT

This review aims to identify and analyze the instruments employed for assessing the overall performance of workers exposed to fluoroscopy during surgical procedures and/or interventional procedures, using the PRISMA methodology.

The studies were located through searches conducted on PubMed, Web of Science, Lilacs, ScienceDirect, B-ON, EBSCOhost, and EBSCO Discovery Service on March 27, 2023. Additional studies were identified using backward and forward citation techniques. The PEO strategic model was followed. The search spanned studies published between 2012 and 2022. The quality of the studies underwent assessment using the Joanna Briggs Institute checklist for analytical cross-sectional studies.

Out of the 23 studies identified, encompassing 3604 individuals, 12 (52%) addressed the reliability and/or validity of the instruments, while 3 (13%) focused on the development and psychometric testing of the instruments. Only 5 instruments (23%), validated and reliable, exclusively evaluated occupational radiological protection. The predominant dimension covered was knowledge (82%, $n = 19$). The population was assessed in 18 studies, pre- and post-intervention in 2 studies, and 21 studies provided recommendations or tools for improvement. Individuals in the studies utilized passive dosimeters (ranging from 5% to 98%), thyroid shields (15% to 98%), and aprons or lead skirts/coats (28% to 99%). The evidence quality was moderate (6/8).

This study underscores the imperative to enhance compliance with protective and monitoring equipment. Furthermore, additional information is warranted concerning the validity and reliability of the instruments used, as well as the development of instruments that are both valid and reliable.

1. Introduction

In 2020, 24 million procedures use fluoroscopy, marking a sixfold increase in 12 years (International Atomic Energy Agency [IAEA], 2022; United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR], 2022). Over the years, interventional procedures have become more complex, potentially requiring more radiation time and higher exposure doses. This situation raises occupational Radiation Protection (RP) (Hammami et al., 2021; International Commission on Radiological Protection [ICRP], 2018).

Exposure to ionizing radiation can be detrimental to the health of workers and may reduce their hope and quality of life as a result of stochastic and/or deterministic effects (Direção-Geral da Saúde, 2016). Stochastic effects, such as genetic aberrations and cancer, occur randomly and have no defined limit, while deterministic effects manifest when exposure exceeds a specified limit, leading to outcomes such as skin changes (Bartal et al., 2016).

During interventions and surgical procedures requiring fluoroscopy, workers often find themselves close to the radiation source. It is imperative to implement all necessary protective measures to minimise

Abbreviations: CPE, Collective Protective Equipment; HDI, Human Development Index; JBI, Joanna Briggs Institute;; KAP, Knowledge, Attitude and Practice;; PEO, Population, Exposure and Outcome;; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses;; RP, Radiation Protection;; PPE, Personal Protective Equipment;.

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exposure while maintaining clinical efficacy and avoiding increased patient exposure. Hence, the management of occupational protection should be seamlessly integrated with patient protection, requiring the RP team's familiarity with these procedures (ICRP, 2018). On a global scale, there is growing concern for awareness, education, information dissemination, training, and the implementation of safety measures and techniques. Despite technological advancements aiming to enhance equipment safety, it remains crucial to ensure that safety measures are effectively in place. The World Health Organization [WHO] is actively driving a global initiative on radiation safety in the healthcare sector, intending to promote the safe and effective use of radiation. Improper use and inadequate protection can introduce avoidable risks (World Health Organization [WHO], 2023).

In advocating for workplace health, workers constitute the fundamental elements. The health of those engaged in work is a valuable asset that necessitates protection through prevention strategies grounded in technical and scientific knowledge, risk assessments, study results, and subjective evaluations (Cardoso, 2016). The safety culture within any organization mirrors the attitudes, behaviours, and actions of its stakeholders towards safety (Coldwell et al., 2015). Consequently, an RP culture is crucial for safeguarding workers, presenting itself as a multifaceted issue intertwined with other facets like knowledge, radiation awareness, regulatory compliance, adherence to protective equipment and dosimetry usage, education, and training (Coldwell et al., 2015; Rose et al., 2018). The attitude towards RP stands as a fundamental organizational value and a cornerstone for fostering good practices in RP. A robust RP culture yields positive impacts on workers, promoted through adherence to protective equipment, utilization of monitoring devices, and the implementation of measures to optimize exposure dose (Rose et al., 2018).

Understanding the underlying reasons for gaps in RP practices is crucial for developing effective strategies that promote optimal application. Emphasis should be placed on building an RP culture that enhances worker engagement, supported by educational initiatives and evidence-based practices (Lewis et al., 2022). The availability of validated and reliable instruments offers opportunities to monitor behaviours that lead to unsafe outcomes. This allows the design of early interventions to support safe practices in the workplace. Furthermore, it facilitates the internal and national comparisons of results and enables external benchmarking with other countries.

To our knowledge, no prior study has explored the specific scope addressed in this research. In the realm of RP, the only existing systematic literature review by Behzadmehr et al. (2021) focused on determining the knowledge, attitude, and practice (KAP) of healthcare workers towards RP. However, this review is not tailored for workers exposed to fluoroscopy during surgeries and interventional procedures.

The primary objective of this study is to identify, evaluate, and compare instruments used to assess overall performance in occupational RP specifically during exposure to X-radiation from fluoroscopy equipment in surgical and/or interventional procedures. Additionally, the study aims to analyze the outcomes reported in these studies.

2. Methods

This systematic review followed the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (Page et al., 2021) and the Joanna Briggs Institute (JBI) guidelines (Moola et al., 2015) to ensure transparency, comprehensiveness, precision, and overall quality of the results. However, it's important to note that the review protocol was not registered.

2.1. Research question and eligibility criteria

The research was driven by the question: "What instruments/questionnaires have been used to assess the attitudes, knowledge, practices, perceptions, safety, behaviour, awareness, and protection of workers exposed to X-radiation from fluoroscopy equipment during surgical procedures and/or interventional procedures and what are the results?"

The eligibility criteria were established following the PEO strategic model (Donato and Donato, 2019; Moola et al., 2015; Sousa et al., 2018). The acronym PEO was utilized as follows: Population (P) - healthcare workers; Exposure (E) – X-radiation from fluoroscopy equipment during surgical procedures and/or interventional procedures; and Outcome (O) - questionnaire as an instrument to assess attitudes, knowledge, practices, perceptions, safety, behaviours, awareness and protection.

The eligible studies followed these inclusion criteria:

- Population - workers exposed to fluoroscopy;
- Workplaces - intervention rooms and/or operative block;
- Health care - humans;
- Research instrument - questionnaire;
- Type of research - quantitative studies;
- Language - Portuguese, English, Spanish and French;
- Full text access - Full open access and institutional subscription publications;
- Publication - From 1 January 2012 to 31 December 2022 (Table 1).

2.2. Information sources

In the initial phase, studies were sourced from databases (EBSCO-Host, ScienceDirect, LILACS and Web of Science), search engines (PubMed and EBSCO Discovery Service) and library databases (B-ON) on 27 March 2023. Subsequently, manual methods involved backward and forward citation techniques. The backward citation technique entailed examining the bibliographic references of the studies deemed included in the first phase. The forward citation technique involved analysing the studies that cited the studies considered included in the first phase, using the 'cited by' option in Google Scholar. Additionally, for inclusion in this phase, studies were required to possess a validated instrument/questionnaire.

2.3. Search strategy

An advanced search was carried out in the databases, search engines and library databases using Boolean operators (AND and OR) and special

Table 1
Eligibility criteria.

	Inclusion criteria	Exclusion criteria
Population (P)	Healthcare workers	- Any other population under study; - Directed to veterinarians
Exposure (E)	X-radiation from fluoroscopy equipment in surgical and/or interventional procedures	- Targeted to another type of exposure to ionizing radiation - Directed to other environments - Not limited to surgical and/or interventional procedures
Outcomes (O)	- The questionnaire as an research instrument; - Assess attitudes, knowledge, practices, perceptions, safety, behaviours, awareness and protection	- Other research instruments (e.g. interviews) - Directed towards exposure dose study -Objective of the study outside the research interest
Other features	- Quantitative studies - Publications in Portuguese, English, Spanish and French - Published between 1 January 2012 and 31 December 2022 - Full open access and institutional subscription publications	- Qualitative or mixed studies - Publications in other languages - Published before or after the defined date. - No access to full text

characters (asterisks and brackets) to improve the search strategy through different combinations. The terms were determined based on Medical Subject Headings (MeSH) and keywords in relevant studies. The same or the closest possible search expression: (Occupational) AND (knowledge* OR attitude* OR practice* OR "KAP" OR perception* OR awareness OR safe* OR behaviour* OR protection) AND ("C-ARM" OR "X-ray" OR fluoroscopy OR "image intensifier*" OR "X-radiation") AND (questionnaire* OR survey* OR scale* OR "self-report*" OR instrument*). The search fields were restricted to "titles, subjects and abstracts", the time delimitation between 1 January 2012 and 31 December 2022 and "humans" (Appendix A).

2.4. Selection process

The articles were systematically managed using Rayyan (Ouzzani et al., 2016) with Zotero utilized for double-checking duplicate articles evaluations. The selection process involved three distinct phases: 1- Duplicate studies were identified and removed using both Rayyan and Zotero; 2- Titles and abstracts of articles were evaluated in Rayyan and categorized as "include" or "exclude"; 3- Full texts of articles deemed relevant and previously categorized as "include" were thoroughly read. Articles were reclassified as "include" or "exclude" in Rayyan, with explicit documentation of exclusion reasons. A second researcher checked the database after duplicates were removed.

2.5. Data extraction

The data extraction process involved a thorough review of each selected article based on Popay et al. (2006), were organized into a table capturing essential information for the study, including Author(s) and year of publication; the aim of the study; participant characteristics and country of study; sample/population details; data extraction and instrument specifics; categories or domains/dimensions and corresponding indicators/variables; main outcomes; and limitations acknowledged in the studies.

2.6. Data synthesis

A narrative synthesis of the data was conducted, categorizing the studies into 3 groups based on the following criteria:

- Diagnosis – studies presenting an assessment of the population/sample;
- Intervention – studies assessment an intervention;
- Tools – studies identifying measures for improvement or constructing and validating an evaluation tool to promote improvement.

2.7. Quality appraisal

The JBI checklist for analytical cross-sectional studies was employed to assess bias risk in the selected studies. It evaluates methodological quality regarding bias in design, conduct, and analysis (Moola et al., 2020). The checklist, comprising 8 questions, examines inclusion criteria, sample details, validity, reliability, objectivity, standardization, confounding factors, and statistical analysis appropriateness. The first author evaluated each item, categorizing methodological quality as "Low" (up to three "Yes" responses), "Moderate" (six "Yes" responses), or "High" (seven or more "Yes" responses). Only "Yes" responses were tallied for classification (Moola et al., 2020; Réus, 2021).

3. Results

The search strategies yielded 567 articles, of which 98 were found in B-on, 30 in EBSCOhost, 201 in EBSCO Discovery Service, 60 in PubMed, 55 in Web of Science, 13 in Lilacs and 323 in ScienceDirect (110 of which remained after merging duplicate studies, 205 of which were eliminated automatically by Ryyan and 8 with manual confirmation).

After excluding duplicate articles, 206 automatically in Rayyan and 339 by manual confirmation, 235 articles remained to check the eligibility criteria.

In the title and abstract analysis stage, 215 articles were excluded, leaving 20 articles for full-text analysis. Upon further examination, 13 articles met the eligibility criteria, while 7 were excluded for the following reasons: not exclusively quantitative studies ($n = 2$); written in Polish language ($n = 1$); radiation exposure not exclusively from fluoroscopy equipment ($n = 3$); and evaluation of exposure dose (n = 1). Consequently, 13 articles were included in this study from databases, search engines and library databases (see Appendix A).

Regarding studies identified through other methods, manually, the titles and abstracts of 173 articles citing the 13 included articles were analysed. Among the 16 fully analysed articles, only 6 met the inclusion criteria, resulting in the exclusion of 10 articles (see Appendix B). Out of the 282 bibliographic references found in the 13 included articles, only 30 articles met the eligibility criteria after a thorough analysis of the title and abstract. After analysing full-text, only 4 articles met the inclusion criteria, leading to the exclusion of 26 articles (see Appendix B). The reasons for exclusion included: radiation exposure not exclusively from fluoroscopy equipment ($n = 5$); Persian language ($n = 1$); lack of access to full-text ($n = 3$); the instrument not validated or not referenced ($n = 24$); and unclear population characteristics regarding fluoroscopy exposure (Fig. 1). The 23 included studies were published.

3.1. General characteristics of the included studies

The primary objective of this review, the results of the included studies are shown in Table 2, as well as the main characteristics of the included studies in order to best answer the research question. These studies were conducted globally: 7 in Europe, 2 in Africa, 7 in Asia, 6 in the Americas, and 1 in Turkey (transcontinental), reflecting diverse perspectives. Included studies were from countries with very high HDI (61%, $n = 14$), high HDI (35%, $n = 8$), and medium HDI (4%, n = 1).

The studies included a total of 3604 individuals, with sample sizes ranging from 29 to 904. Additionally, one study involved 53 centres but did not mention the number of individuals involved (Marinskis et al., 2013). Goula et al. (2021) shared the same sample as Chatzis et al. (2021), and Schroderus-Salo et al. (2019) shared the same sample as Hirvonen et al. (2019). Therefore, only the number of individuals in 20 studies was counted.

Out of the 2651 participants in the 15 studies that reported gender distribution, the majority (64%) were male (1692 vs 959). In 5 studies, the female gender was predominant.

The average age and age range of participants were mentioned in 65% of the studies ($n = 15$). The studies assessed individuals aged 18 to over 60. The majority of the samples were in their thirties and forties, with average ages ranging from 31 to 49.

The professionals involved were doctors (surgeons, urologists, anesthetists, orthopedists/traumatologists, neurosurgeons, neurologists, radiologists and cardiologists), technicians and nurses.

The 13 articles included using databases, search engines and library databases searches were published between 2013 and 2022, with 77% of the studies published in the last 5 years. The 10 articles included using other methods were published between 2013 and 2021, with 80% of the studies published in the last 5 years. Thus, of the 23 articles included in our study, 78% were published in the last 5 years (Appendix B).

The articles included in this study had 270 citations. The most cited articles were Friedman et al. (2013) with 67 citations, Hirvonen et al. (2019) with 32 citations, Marinskis et al. (2013) with 29 citations, and Tok et al. (2015) with 27 citations (Appendix B).

Although some studies do not mention it, it is believed that all included studies were cross-sectional, and descriptive. According to the results of the JBI checklist for analytical cross-sectional studies (Appendix C), the studies included were considered to be of moderate

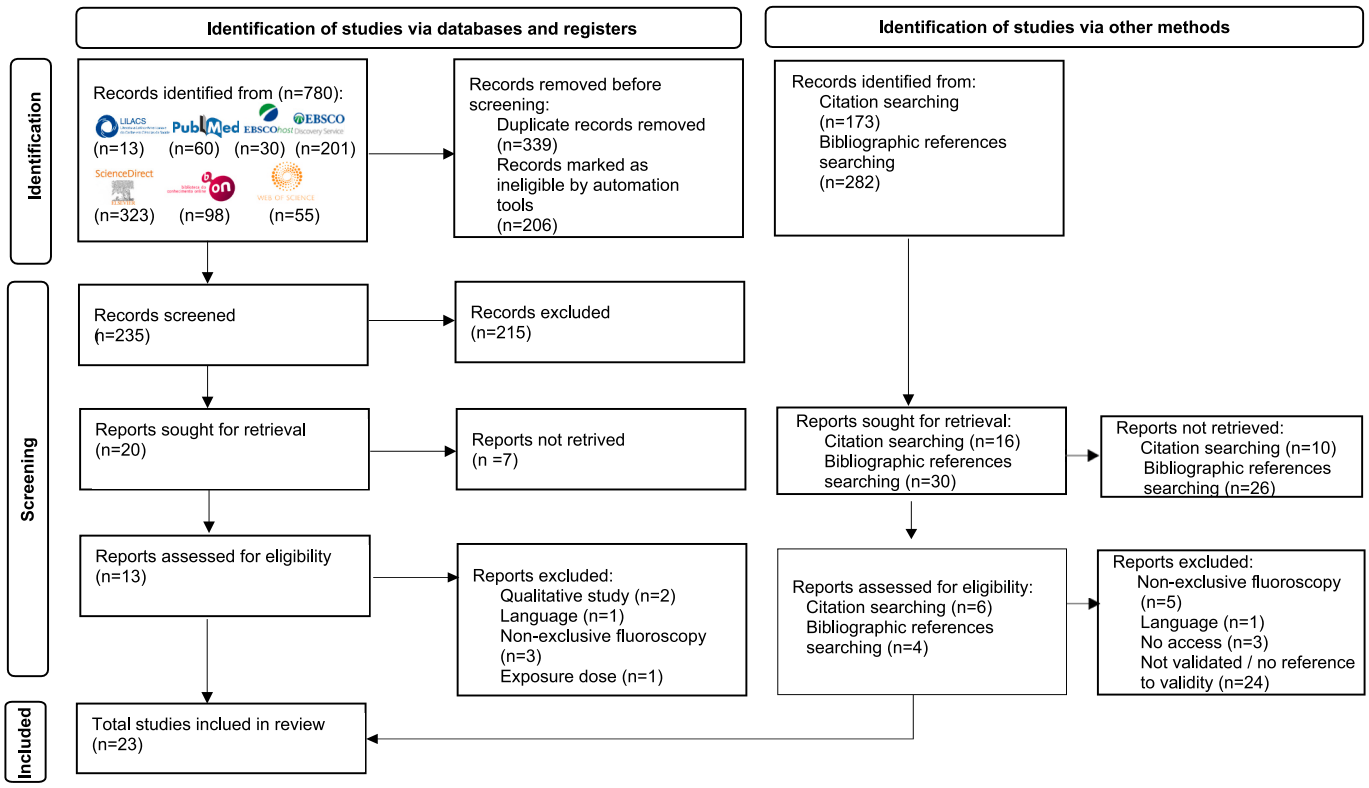

Fig. 1. Study selection flowchart adapted from the PRISMA methodology (adapted from.

methodological quality, as the average score obtained was 6 out of 8, with 39% ($n = 9$) having a high, 57% ($n = 13$) a moderate and 4% (n = 1) a low methodological quality. The questions with the highest risk of bias (43%) were those related to the validity and reliability of the instrument used.

3.2. Instruments, validation and reliability

This study identified 21 different questionnaires. Hirvonen et al. (2019) used Schroderus-Salo et al. (2019) instrument, and Goula et al. (2021) used Chatzis et al. (2021) instrument. The researcher developed 18 (86%) of the instruments. Roy et al. (2021) mentioned using a pre-designed and pre-tested instrument without specifying the author, while Alshabi et al. (2022) and Keshtkar and Masoumi (2021) used instruments developed by others.

Eighteen instruments were self-administered (86%). Questionnaire administration method were unclear in 3 studies. The instruments lengths ranged from 10 items to 95 items. In 65% ($n = 15$) of the studies analysed, the instruments used were accessible.

Of the 23 studies, 52% ($n = 12$) mentioned the validity and/or reliability of the instruments. Of these, 9% ($n = 2$) were obtained from databases, search engines and library databases, 13% ($n = 3$) focused on developing and testing a questionnaire, and 13% (n = 3) included patient RP questions. Tok et al. (2015) mentioned their instrument was not validated (4%), while 43% ($n = 10$) didn't mention validity or reliability.

Reliability and/or validity were addressed in 12 studies, involving to 10 instruments. One instrument lacked validation and reliability. Eight instruments (80%) had content validity assessed by expert panels, 2 (20%) had face validity, 4 (40%) had content validity determined by exploratory factor analysis and/or principal components, and 6 (60%) underwent reliability analysis using test-retest and/or Pearson's coefficient and/or Cronbach's alpha coefficient. Among the instruments, 7 (33%) demonstrated both validity and reliability, while 3 (14%) showed validity only (Appendix D).

Expert panels varied in composition, with members ranging from 4 in Shafiee et al. (2020) to 10 in Keshtkar and Masoumi (2021). Areas of expertise included nursing, nuclear medicine, psychometrics, medicine (radiologists, ophthalmologists and orthopedists), radiation specialists, medical physics, occupational health, epidemiology, academics, radiology technicians and biostatistics.

Upon analysis, 18 studies (78%) evaluated the population/sample, 2 (9%) conducted pre- and post-intervention evaluations, and 21 (91%) provided suggestions for improvement or assessment tools to promote enhancement.

3.3. Categories or domains/dimensions and their indicators/variables

The assessed categories or domains/dimensions in the studies included knowledge; practices/behaviours; safety policies; perception of safety; perception of disease risk; depressive symptoms; degree of concern; occupational health and safety; attitudes; feelings and symptoms; misconceptions; improvement measures; performance and RP implementation; and RP capability.

The knowledge assessment targeted radiation physics, protection and monitoring equipment, biological effects, education and training in RP, exposure limits, and dose minimisation measures. The assessed indicators were mainly related to these topics.

The indicators practices/behaviours mainly encompass the use of protective equipment and dosimetry, radiation-emitting equipment, frequency of exposure, exposure limits per procedure, strategies to minimise exposure doses, level of practices related to exposure, reasons for non-use of protective equipment and monitoring, practices and satisfaction during pregnancy, and proficiency in implementing RP.

Safety policies were assessed based on indicators such as availability of occupational health consultations, identification of RP responsible personnel, presence of signage, knowledge regarding when to change personal protective equipment (PPE) and availability of PPE.

Safety perception assessment included indicators such as feeling safe, checking equipment validity or effectiveness before use, presence of

Table 2
General characteristics of the studies.

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population: 1. Target population; 2. Year of data extraction 3. Sample (Sample/ Ratio/ final sample); 4. Age ($\bar{x} \pm \sigma$) 5. Genre (Male/Female)	Data extraction and instrument: 1. Method of data extraction 2. Means of data extraction 3. Instrument – origin 4. Instrument – items 5. Instrument – access 6. Instrument - validity and reliability 7. Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/Dimensions and their indicators/ variables	Main results		
Identification of studies through databases	A1 Diagnosis Tools	Mzoughi et al. (2021) _____ Tunisia	Assess knowledge about ionizing radiation, its effects and RP	**1.** Cardiac catheterization nurses (NS) - 6 university hospitals **2.** 2018 **3.** 50/58%/29 **4.** 35 ± 11 years **5.** M17/F11	**1.** Self-administered questionnaires **2.** Manuscript - Hand delivery and questionnaire drop box **3.** Authors **4.** 40 **5.** Not available **6.** NR **7.** Descriptive, transversal, prospective	Knowledge • Nature of x-rays and dose limits; • Protective equipment. • Biological effects and risks of x-rays. Practice/Behaviour • Protective equipment • Monitoring devices Safety Policies • Occupational Health consultation • Communication	Knowledge • 0% - Nature of x-rays and exposure limit • 69% - RP Training Practice/Behaviour • 59% used a dosimeter • 69% wore a lead apron, 45% thyroid shield and 69% lead glasses Safety Policies • 59% had an Occupational Health consultation • 0% knew the RP reference people at the institution	• Sample size	Moderate (4/8)
	A2 Diagnosis Tools	D'Avino et al. (2019) _____ Italy	Assess the status of knowledge of the new dose limit for the lens of the eye and RP culture	**1.** Doctors (MD), Radiology Technicians (RT) and Intervention NS (cardiology, hemodynamics, urology and orthopedics) – 5 hospitals in the Campania region **2.** 2019 **3.** 82/78%/64 (21MD + 26TR +17NS) **4.** NR **5.** NR	**1.** Questionnaires + confirmation of veracity with department manager and RP officer **2.** NR **3.** Authors **4.** 10 **5.** Available **6.** NR **7.** NR	Knowledge • Directive 2013/59/ EUROTOM Practice/Behaviour • Protective equipment • Monitoring device	Knowledge • 19% - They knew the new dose limit for the eye of the lens Practice/Behaviour • 83% wore a lead apron, 36% lead glasses and 57% thyroid shield • 6% wore to eye lens dosimeters, 16% extremity dosimeters and 98% whole-body dosimeters	• Sample size • Geographical confinement	Moderate (5/8)

Coding	**Groups**	**Author, (Year of publication), Country**	**Objective**	**Characteristics of the Sample/population:** **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	**Data extraction and instrument:** **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and	**Outcomes**		**Limitations**	**Methodological quality**
						Categories or Domains/ Dimensions and their indicators/ variables	**Main results**		

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
					Categories or Domains/ Dimensions and their indicators/ variables	Main results		
				reliability **7.** Type of study				
Identification of studies through databases, search engines and library databases	A3 Diagnosis Tools	Alshabi et al. (2022) _____ Saudi Arabia	Assess awareness and knowledge about the safety of radiation exposure	**1.** Orthopedic surgeons in private and governmental hospitals in Al-Madinah city **2.** 2022 **3.** 100/57%/57 **4.** NR **5.** M50/F7	**1.** Questionnaires **2.** NR **3.** Bukhary, et al (2021) **4.** 19 **5.** Through bibliographic reference **6.** Construct validity by exploratory factor analysis and principal components (no details) **7.** Descriptive transversal	Knowledge • Training. Practice/ Behaviour • Frequency of exposure. • Radiation emission. • Protective equipment. • Monitoring device • Distance to the radiation source; • C-Arm Position Safety Perception • Feeling of safety • Validity or effectiveness of protective equipment. • Warning signs on the door • Safety practices Perception of disease risk • Concern about exposure.	Knowledge • 11% - Radiation safety training • 33% - Training to use fluoroscopy Practices/Behaviours • 53% allowed anyone to use the radiation-emitting equipment guided by the surgeon • 79% wore a lead apron, 18% lead apron + thyroid shield, 2% gloves and 2% nothing • 5% used a dosimeter • 58% stayed 2 steps from the radiation source and 33% didn't worry about the distance and 9% stayed 3 meters away • 46% placed the radiation source under the operating table, 32% on the operating table and for 23% it wasn't important Safety Perception • 19% felt safe • 12% checked the effectiveness or validity of the protection, 89% knew about this factor and 2% checked before using • 58% reported that there were no warning signs on the room door, 14% weren't sure and 28% confirmed the presence • 44% had a safe practice, 42% didn't and 14% didn't know they had to have one Perception of disease risk • 84% were worried all the time and 16% at some point about radiation	• Sample size • Answer rate	Moderate (6/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population:	Data extraction and instrument:	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	Main results		
	A4	Marinskis et al. (2013) Centres: Armenia-1; Austria-1; Belgium-1; Bulgaria-1; Denmark-4; France-3; Germany-3; Greece-2; Italy-11; Lithuania-2; Monaco-1; Netherlands 5 Romania-1; Spain-9; Sweden-2; United Kingdom-6.	Evaluate experience and practices of working with X-radiation during electrophysiolo-gy and implantation procedures	**1.** 53 European Heart Rhythm Association centers – 69% were university hospitals, 7% private and 24% other hospitals **2.** 2011 **3.** NR **4.** NR **5.** NR	**1.** Self-administered questionnaires **2.** Email **3.** Authors **4.** NR **5.** NR **6.** NR **7.** NR	Safety Practices/ Behaviours/ Policies • Technical exposure parameters • Individual monitoring • Exposure limits per procedure • Fluoroscopy equipment • Monitoring device • Time limit per procedure • Safety measures and techniques • Protective equipment • Mapping and robotic systems Perception of disease risk • Possible occupational diseases	Safety Practices/Behaviours/ Policies • 53% use low pulse rate/ second to reduce exposure (3-6) • Individual monitoring in the majority (1 center doesn't have it) • 61% knew about exposure limits • 19% used biplane fluoroscopy in ablations and 4% in implantations • Minimise distance between detector and patient (98%), collimation (91%); verbal information about fluoroscopy times (86%) • 67% use dosimeters above the lead apron, 59% beneath the lead apron and 35% finger dosimeters • Implantations ➔ 74% had no limits and 26% defined 60 minutes of fluoroscopy and 4 hours of procedure • Ablations ➔85% had no limit and 15% had a limit of 1 hour of fluoroscopy • 94% wore a lead apron, 98% a thyroid shield, 89% lead glasses, 84% a lead glass wall; 71% shielding on the table, 27% sterile radiation absorbing pads, 32% gloves, 19% mobile radiation protection cabine • 73% use mapping systems and 11% robotic systems Perception of disease risk • The majority didn't observe any possible health damage, but 2% mentioned dermatitis and 4% cancer in colleagues	• NR	Low (3/8)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Mean of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	Main results		
Identification of studies through databases, search engines and library databases	A5 Diagnosis Tools	Shafiee et al. (2020) _____ Iran	Assess knowledge and practice of RP principles during intervention procedures	**1.** MD (urologists, orthopedists, surgeons, neurologists and radiologists) and C-Arm Fluoroscopy Guided Procedures Nurses **2.** NR **3.** NR/NR/215 (41 MD + 174 NS) **4.** 72% between 26-45 years old, 9% over 45 years old, 19% under 26 years old **5.** M79/F136	**1.** Questionnaires + check practice list **2.** NR **3.** Authors **4.** 17 questions +10 check list **5.** Available **6.** Content validity – expert panel (3 radiologists and physicists); Construct reliability analysis - test- retest with Cronbach 's alpha = 0.88 **7.** Descriptive	Knowledge • ALARA, dose limits, Justification, optimisation, radiation source, scattered radiation, biological effects, radiosensitivity and positioning in relation to the radiation source. Practice/Behaviour • ICRP Guidelines and ALARA principles	Knowledge • 87% - the correct place to use the dosimeter • 40% - shielding • 24% lead glasses and 58% on gloves • 26% - positioning to minimise exposure • 26% - radiation source and scattered radiation. • 28% - biological effects • 88% radiosensitivity of foetuses and 16% of radiosensitive organs • 9% - exposure dose limits • 27% of NS and 66% of MD had courses/training Practice/Behaviour • 87% chose to use a dosimeter, 16% used it inappropriately and 10% forgot to use it • 34% wore PPE (23% lead glasses, 35% thyroid shield and 42% lead aprons • 26% properly used shielding equipment	• NR	High (8/8)
	A6 Diagnosis Tools	Tok et al. (2015) _____ Turkey	Analyse and evaluate attitudes and knowledge about ionizing radiation	**1.** Workers in urology operating theatre at private and state hospital (28%), training and research (41%) and university hospitals (32%) **2.** 2013 **3.** 183/69%/127 49% NS + 11% TR + 40% others **4.** 32 ± 6 years **5.** NR	**1.** Self-administered questionnaires **2.** Email (Google Docs™) **3.** Authors **4.** 13 **5.** Available **6.** Not validated **7.** NR	Knowledge • Biological effects • Training on effects and protection methods Practices/Behaviours • Frequency of exposure. • Protective equipment. • Use and frequency of the monitoring device Safety Policies • Protection methods used	Knowledge • 89% - Information on harmful effects of radiation. • 44% - Training or education. Practices/Behaviours • 72% wore a lead apron and thyroid shield. • 47% used a dosimeter for monthly and annual measurements, 50% of whom worked in university hospitals and 56% in training and research hospitals and 0% in private hospitals.	• Answer rate • Young population – online questionnaire but young urologists and the rest of the team are especially more involved in these procedures	Moderate (5/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Mean of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	Main results		
							• 100% of TR, 47% of NS and 31% of other professionals used dosimeters. • The rate of use of PPE (lead apron + thyroid shield + lead glasses + gloves) is 21% for the group that received training and 3% for the group that did not have training. Safety Policies • 51% indicated that there were no radiation warning signs, 40% of which were reported in teaching and research hospitals		
A7	Diagnosis	Bazan et al. (2019) _____ Argentina	Measure the use of fluoroscopy in spine surgery, recognize control measures, evaluate the appropriateness of protective equipment and analyse adverse events.	**1.** Surgeons who are members of the Argentine Society for the Study of Spine Pathology **2.** NR **3.** NR/NR/55 **4.** 78% under 50 years old **5.** M53/F2	**1.** Self-administered questionnaires **2.** Email **3.** Authors **4.** 17 **5.** Not available **6.** NR **7.** NR	Practices/Behaviours • Use and techniques of fluoroscopy and RP measurements, frequency and forms of use, monitoring time and percentage of use in minimally invasive surgery. Safety Policies • Protection methods (elements and protection, ownership and replacement) • In the last 10 years, what have been the changes in conditions and surgeries? Perception of disease risk • Possible occupational diseases	Practices/Behaviours • 98% used pulsed radiation emission • They used radiation in: Final control (28%), therapeutic procedure (23%) and localisation (23%) • 85% performed less than 25% of minimally invasive surgeries • 71% wore a one-piece lead apron and 11% a skirt/vest, which was associated with a thyroid shield in 23% and with standing posture, increasing the distance to 2 meters in 29%, but 4% didn't use any measure at all Safety Policies • 5% had their own lead aprons and 10% their lead glasses • 86% ignore when PPE should be replaced Perception of disease risk	• NR	Moderate (4/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Mean of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	Main results		
							• 13% vision changes, 9% thyroid disorders, 5% dermatitis, 4% infertility, with 3% requiring surgery for a thyroid nodules, cataracts or neoplasms		

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/ Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	Main results		
Identification of studies through databases, search engines and library databases	A8 Diagnosis Tools	Roy et al. (2021) _____ India	Assess the awareness and practices regarding occupational exposure to radiation and its risks. Estimate the association of the level of awareness and practices with various factors	**1.** Orthopedic surgeons **2.** 2019 **3.** NR/NR/150 **4.** 42 ±17 years **5.** M148/F2	**1.** Self-administered questionnaires **2.** Email and online messaging (Google Forms®) **3.** Pre-designed, pre-tested and semi-structured questionnaire – no details mentioned **4.** 26 **5.** Noticeable by the results **6.** NR **7.** Transversal	Awareness • Knowledge level. Practices/ Behaviours • Level of practices related to exposure; • Protective measures used • Reasons for not using protective measures or PPE; Perception of disease risk • Concern Improvement measures.	Awareness • 63% - Adequate level of knowledge. Practices/Behaviours • 12% - Adequate practices with equipment. • 9% (n=13) wore some type of equipment, 92% (n=12) wore a lead apron, 15% (n=2) a thyroid shield and 0% wore a lead glasses, gloves and gonad protector • surgeons with more than 10 years of experience had a higher level of knowledge compared to those with less than 10 years, but the level of practice was significantly lower • 82% - They knew how to use the C-Arm, but it was used by a	• Biased answers - dishonest answers by internet search • Non-response rate and incomplete/ wrongly filled forms high number	Moderate (5/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/ Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	Main results		
							technician or assistant • The feeling of discomfort was cited by 70% (n=105) and the lack of adequate equipment by 57% (n=85) as a reason for not using PPE Perception of disease risk • 87% said radiation was a major concern Improvement measures • 65% believed that strict measures would make a difference, 27% didn't and 8% weren't sure • 91% say that adequate training and a health promotion approach would make a difference		
A9	Diagnosis Tools	Barbosa and Silva (2022) _____ Brazil	Understanding the perception of the risk of exposure to ionizing radiation in fluoroscopy procedures	**1.** Orthopedists and Traumatologists **2.** 2020 **3.** NR/NR/141 **4.** 30 to 50 years old – 60% **5.** M119/F22	**1.** Self-administered questionnaires **2.** Email (Google Forms®) **3.** Authors **4.** 34 **5.** Available **6.** NR **7.** Transversal	Knowledge • Risks of ionizing radiation; • Prevention of emitted radiation; • Awareness Practices/ Behaviours • Use of dosimeter and PPE; • Own or provided PPE • Reasons for not using PPE • Prevention measures Safety perception • Feeling of safety Perception of disease risk • Concern	Knowledge • 19% - Training • 77% knew that it was the X-radiation that came from the equipment • They recognized the risks and effects of exposure • 47% knew the RP principles for their protection Practices/Behaviours • 49% wore a lead apron, 34% a thyroid shield and 6% a thyroid shield and lead apron set • 69% wore PPE in all or more than half of surgeries • The reason for not using PPE is cited by 68% as interfering with the procedure, 20% mentions the fact that the hospital doesn't provide PPE and 11% because there is CPE • 18% used a dosimeter and didn't know their exposure doses • 60% walked away during the	• Low response rate	Moderate (6/8)

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Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/ Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	**Main results**		
							exposure • 69% kept their hands outside the primary beam (except when strictly necessary), with 31% moving their hands away • 27% used RP principles for their protection Safety perception • 35% felt safe Perception of disease risk • 79% were worried about radiation and feared developing complications		

Coding		Groups		Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction; **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						1.	**1.**	**Categories or Domains/ Dimensions and their indicators/ variables**	**Main results**	•	
Identification of studies through databases, search engines and library databases	A 10	Diagnosis	Tools	Kaplan et al. (2018) USA	Examine current standards of practice in occupational radiation safety and assess whether they vary by demographics and experience	**1.** Hand and upper extremity surgeons who are members of the American Society for Surgery of the Hand **2.** NR **3.** 3352/27%/904	**1.** Self-administered questionnaires **2.** Email (TypeForm®) **3.** Authors **4.** 18 **5.** Available	Practices/ Behaviours • Standards of practice • Use of PPE and dosimeter • Arm Position Perception of	Practices/Behaviours • 99% used the mini C-Arm and 87% used the standard C- Arm • 58% wore PPE when using the mini C-Arm and 95% when using the standard C-Arm • 55% wore a lead apron and 42% wore a thyroid shield	• Study based on survey responses • 27% of eligible sample • 18 questions – limitation of information	Moderate (5/8)

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Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction; **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
				1.	**1.**	**Categories or Domains/ Dimensions and their indicators/ variables**	**Main results**	•	
				4. NR **5.** M777/F127	**6.** NR **7.** NR	disease risk • Possible occupational illnesses	frequently with the mini C-Arm and 81% wore a lead apron and 63% used a thyroid shield frequently with the standard C-Arm • The majority used both devices in the recommended positions, recommended protection to the team and minimised the use of fluoroscopy regardless of the equipment • 30% routinely used a dosimeter • In 88% of surgeons who used mini C-Arm and 95% standard C-Arm there were no changes in the use of protective equipment in the last 5 years Perception of disease risk • 2% reported having cataracts and 2% thyroid pathology		
A11	Intervention Tools	Brun et al. (2018) France	Evaluate RP practices and knowledge before and after training	**1.** Surgeons and anesthetists from a public hospital center pre and post training **2.** 2016 **3.** 103/87%/90 (pre) ➔103/39%/35 (post) **4.** 43.8±12 years (pre) ➔48.5±11 years (post) **5.** M51 / F39 (pre)➔ M24/ F11 (post)	**1.** Self-administered questionnaires **2.** Pre-training manuscript and electronically 1 month later **3.** Authors **4.** 23 **5.** Available **6.** No **7.** NR **8.** Descriptive, transversal prospective	Knowledge • Self-evaluation • Exposure limits • ALARA principle • Distance/dose relationship • Biological effects • Monitoring • Medical appointment • Training • Position relative to the radiation source	Knowledge • 13% - Had training and recognised insufficient knowledge • 5.5/16 before training ➔ 9.5/16 after training Practices/Behaviours • 92% wore a lead apron, 52% a thyroid shield, 6% lead glasses • 53% used a passive dosimeter, 18% active (in real time) and 50% positioned the dosimeter correctly	• Difference between the pre- and post-training sample (age and size) • Collection method • Failure to check in the field • Reevaluate after a longer period of time	Moderate (6/8)

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				1.	**1.**	**Categories or Domains/ Dimensions and their indicators/ variables**	**Main results**	•	
						Practices/ Behaviours • Protective equipment • Monitoring devices Perception of disease risk • Risk of cataracts Safety Policies • Occupational health consultation	• 0% used collective protection • 3.3/7 before training ➔ 3.3/7 after training ➔ 74% change in after training practices Perception of disease risk • 47% reported that they are at risk of cataracts Safety Policies • 14% had an occupational health consultation		
A12	Intervention Tools	Walsh et al., (2019) USA	Assess knowledge about radiation safety and determine whether a safety intervention radiology would improve knowledge	**1.** Orthopedic surgeons at a lecture **2.** NR **3.** 41/100%/41 ➔ pre-lecture (19 residents +22 faculty members) and 41/ 68%/28 ➔ post-lecture (11 residents+27 faculty) **4.** NR **5.** NR	**1.** Self-administered questionnaires **2.** Online platform - 1 week before the lecture and 2 weeks after the lecture **3.** Authors **4.** 17 **5.** Not available **6.** NR **7.** NR	Knowledge • Self-evaluation	Knowledge • Residents self-rated pre-lecture knowledge at 2.8 (scale of 1-5 with a range of 1-4, meaning a score of 48%) and post-lecture at 3.1 (53%) • Faculty members self-rated knowledge pre-lecture at 3.5 (50 %) and post-lecture at 3.1 (46%) (range of 2-5) • 70% of residents and 80% of faculty members felt that the lecture was an added value despite statistically didn't improve their scores	• Small sample • Results cannot be generalized • Difference in pre and post lecture sample • Anonymous searches • Selection bias	Moderate (5/8)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/	Data extraction and instrument: **1.** Method of data extraction; **2.** Means of data	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and	**Main results**		

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Coding		Groups		Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **6.** Age ($\bar{x} \pm \sigma$) **4.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction; **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
								Categories or Domains/ Dimensions and their indicators/ variables	Main results		
						Ratio/ final sample); **6.** Age ($\bar{x} \pm \sigma$) **4.** Genre (Male/Female)	extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	**their indicators/ variables**			
Identification of studies through databases	A13	Diagnosis	Tools	Friedman et al. (2013) _____ USA	Assess attitudes and occupational radiation safety practices	**1.** Urologist in training **2.** December 2011 - January 2012 **3.** 1350/12%/165 **4.** NR **5.** NR	**1.** Self-administered questionnaires **2.** E-mail – distribution from directors and coordinators of Urology residency programmes **3.** Input of Residents and fellows - accepted by the authors **4.** 10 **5.** Not available **6.** NR **7.** NR	Knowledge • level of training, sources of education, perception of adequate training, • knowledge of dose limits Practices/ Behaviours • Use of PPE and dosimeter • Application of the ALARA principle • Practices and satisfaction during pregnancy	Knowledge • 55% reported that the source of training was mandatory postgraduate training and 58% through the department • 53% felt adequately trained Practices/Behaviours • 99% wore a lead apron, 73% often wore a thyroid shield, 13% lead glasses and 1% gloves • 73%-78% reported lack of PPE availability • 88% practised ALARA principles • 92% moved away from the radiation source • 30% never used a dosimeter, 56% never received a dosimeter • 9% wore a dosimeter, a lead apron and a thyroid shield • 46% correctly identified the exposure limit value • 30% of pregnant women were satisfied with the level of exposure • Trainees trained in the departments had more compliance with PPE, dosimeter and ALARA principles, higher satisfaction rate and identified the exposure dose limit	• Low response rate; • 10 questions - limitation of information; • Number of women who became pregnant; • Geographical area; • reporting bias	Moderate (5/8)
Identification of studies through bibliographic references	B1	Diagnosis	Tools	Hirvonen et al. (2019) _____ Finland	Characterise knowledge about the use and safety of radiation	**1.** NS in operating theatres, first aid clinics and cardiology laboratories – (4 university hospitals and 4 central) **2.** 2017 **3.** 1500/17%/252 **4.** [18-27] = 12%; [28-37] = 31%; [38-47] =	**1.** Self-administered questionnaires **2.** Email – through supervisors **3.** Authors➔ Schroderus -Salo et al., (2019) **4.** 33 **5.** Available **6.** Face validity;	Knowledge • RP • Guidelines for the safe use of ionizing radiation • Radiation physics, biology and principles of the use of radiation	Knowledge • It ranged from 3.8-6.5 (on a 10-point scale), with an average of 6.5 ±2.4 in the dimension of knowledge about RP, 4.8±2.6 in the dimension of guidelines for the safe use of radiation and 3.8±2.3 in the dimension of radiation physics and principles of radiation use.	• Difference in sample sizes of the 3 areas of activity • Wide confidence intervals • Difference in show size according to gender • Low response rates	High (8/8)

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Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **6.** Age ($\bar{x} \pm \sigma$) **4.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction; **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
					Categories or Domains/ Dimensions and their indicators/ variables	Main results		
				26%; [48-57] = 23%; Above 57 =7 **5.** M37/F215	Content validity with CVI = 0.83; Construct validity - by exploratory factor analysis; Internal consistency reliability analysis by Cronbach 's Alpha (Cronbach =0.93-0.96) **7.** Transversal			
B2	Diagnosis Tools	van Papendorp et al. (2020) _____ South Africa	Assess knowledge, awareness and practices in relation to PR	**1.** Orthopedic surgeons – from the University of Pretoria which includes 3 hospitals) **2.** 2018 **3.** 56/79%/44 **4.** NR **5.** NR	**1.** Self-administered questionnaires **2.** Manuscript - academic meeting **3.** Authors **4.** 14 **5.** Available **6.** Content validity - Expert panel (radiologists, orthopedists and 1 biostatistician) **7.** Descriptive	Knowledge • Level of training, suitability and knowledge • ALARA, inverse square law, annual dose limits, and exposure minimisation methods Practices/ Behaviours • Frequency and need for fluoroscopy • Use of dosimeters and practices in relation to protective equipment Perception of disease risk • Vulnerability and adverse effects	Knowledge • 23% knew the meaning of the ALARA principle, 20% identified the annual dose limit, 70% identified the correct definition of the inverse square law • 61% knew that reducing the dose for the patient would reduce the dose for the worker; 64% knew that shielding equipment is highly attenuating • 50% thought that being closer to the radiation source would be more protective Practices/Behaviours • 77% used fluoroscopy in more than half of the procedures performed • 7% used a dosimeter • 73% felt they received adequate training • 93% always wore a lead apron and 25% wore a thyroid shield. • Gloves, lead glasses, mobile protection, table and roof protection were considered unavailable and other reasons such as discomfort and impracticality were also mentioned for not using them. Risk perception • 89% believed they were vulnerable and adverse effects	• 5 questionnaires were partially completed – printed questionnaire • Scope of the expert panel	Moderate (4/8)

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						Categories or Domains/ Dimensions and their indicators/variables	Main results		
Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/ Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	Main results		
Identification of studies through bibliographic references	B3 Diagnosis Tools	Chow et al. (2013) _____ Canada	Determine the level of risk perception for cataract formation, level of awareness of cataract formation, level of awareness of the existence of dose limits and RP practices	**1.** Orthopedic surgeons who are members of the Canadian Orthopedic Association **2.** 2010 **3.** 1132/23%/264 **4.** <31 = 10%; [31-40] =36%; [41-50] = 22%; [51-60] = 16%; Above 60 =16 **5.** NR	**1.** Self-administered questionnaires **2.** Email **3.** Authors **4.** NR **5.** Not available **6.** Content validity - Expert panel (2 orthopedists, 1 ophthalmologist, 1 RT, orthopedic research team and 1 senior orthopedist); Face validity - pilot test **7.** Descriptive	Risk perception • Risk perception and awareness of the risk of cataract formation • Awareness of dose limits to the lens of the eyes Practices/Behaviours • Use of fluoroscopy • Use of RP equipment and strategies • Reasons not to wear lead glasses	Risk perception • 41% believed they were at moderate risk, 8% extreme, 27% minimal and 2% were not at risk • 78% indicated they had sufficient knowledge to estimate the risk • 55% reported being aware of the effects of radiation on cataractogenesis • 26% were aware that there are annual dose limits • 60% were unaware of their dose limits, 26% estimated they were below the limit and 14% equal or above the limit Practices/Behaviours • 56% were classified as using low amounts of fluoroscopy, 30% moderate, and 15% high • 86% wore a lead apron, 61% wore a thyroid shield and 91% never wore lead glasses • Reasons for not using lead glasses: the institution doesnt provide them, they are unaware of the risk of cataracts and they dont know where to buy them	• Answer rate	Moderate (5/8)

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Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/ population:	Data extraction and instrument:	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	Main results		
B4	Diagnosis Tools	Fan et al. (2017) _____ China	Investigate whether the level of knowledge about radiation is associated with psychological distress	**1.** Orthopedic surgeons **2.** 2015 **3.** 500/53%/266 **4.** 37±8 years **5.** NR	**1.** Self-administered questionnaires **2.** Electronically (WeChat) + manuscript (conference) **3.** Authors + validated scales **4.** NR **5.** Through bibliographic references **6.** Validity and reliability of scales **7.** Transversal	Knowledge • Questions - "know little and not concern," "know well but not concern," "know little but concern," and "know well and concern." • Degree of concern • General psychological distress - Kessler scale 10 (K10) Depressive symptoms • Center for Epidemiological Studies Depression Scale (CES-D). Practices/Behaviours • Use of PPE, real-time monitoring, etc.	Knowledge • 43% reported having good knowledge about radiation • Degree of worry and depressive symptoms • 78% considered radiation exposure a major concern • Of those who reported concern (58%), they also reported having little knowledge • Worries were significantly associated with higher scores on the CES-D and K10 ($P < 0.05$) • Of the individuals who reported concerns, those who had less knowledge had higher CES-D and K10 scores than those who reported having good knowledge ($P < 0.05$) • Of those who reported having no worries, those with little knowledge had higher CES-D and K10 scores ($P<0.05$) Practices/Behaviours • 6% did not adopt any protection strategy, 28% wore a lead apron, 11% used real-time dosimetry, 17% a thyroid shield, 3% lead glasses and 35% mobile shielding.	• Sample size • Correlation presented is not the cause-and-effect relationship • It was not possible to identify whether prolonged exposure could induce psychological distress.	High (7/8)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population:	Data extraction and instrument:	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	Main results		

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Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population:	Data extraction and instrument:	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/ variables	Main results		
				1. Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	**1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study				
				4. Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	**6.** Instrument - validity and reliability **7.** Type of study				
Identification of studies through citation bases	B5 Diagnosis Tools	Goula et al. (2021) _____ Greece	Explore the beliefs, the perceptions and the behaviours and research the impact of specific demographic characteristics on these beliefs	**1.** NS, RT, orthopedic surgeons, neurosurgeons, urologists and anaesthesiologists - 1 of the largest public hospitals. **2.** 2021 **3.** 136/97%/132 **4.** [25-34] =13%; [35-44] = 41%; [45-54] = 34%; Above 55=12% **5.** M72/F60	**1.** Self-administered questionnaires **2.** Manuscript **3.** Chatzis et al. (2021) **4.** 95 – (6 dimensions pre pilot test ➔15 dimensions post pilot test) **5.** Available - Chatzis E, et al (2021) **6.** Content validity (6 experts – principal researcher + supervising professor + 1 orthopedic surgeon +1 RT+ 1 radiologists + 1 medical physicist); Face validity (5 experts); Construct validity - analysis of main components (pilot study (n=31); Internal consistency reliability analysis by Cronbach's Alpha = 0.499-0.894) **7.** Transversal	Knowledge • General, basic and advanced RP • Individual dosimetry Occupational health and Safety • Protective equipment Negative attitude towards protective equipment • Discomfort when using PPE • Discomfort due to dirty PPE Negative feelings due to accidental radiation exposure • Fear and anger due to unintentional exposure • Guilt at having been exposed to radiation unintentionally Psychosomatic symptoms due to negative feelings related to radiation Misconceptions • About radiation • Importance and necessity of RP	Knowledge • It was unsatisfactory in terms of general, basic and advanced knowledge of RP • It was satisfactory in terms of individual dosimetry • Less experienced workers had a higher level of knowledge Occupational health and Safety • The hygiene and cleaning of protective equipment were considered inadequate Negative attitude towards protective equipment • A tendency to have a negative attitude towards protective equipment and to feel uncomfortable wearing it Negative feelings due to accidental exposure to radiation • Negative feelings related to radiation didn't seem to be incorporated Psychosomatic symptoms due to negative feelings related to radiation • Less experienced workers were more likely to somatise negative emotions regarding radiation • Misconceptions • The number of mistakes was lower than the control value • Less experienced workers had fewer	• Sample limited to one hospital • Only quantitative studies	High (8/8)

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							misconceptions about the need for protection • The valid and reliable instrument to record perceptions, beliefs and behaviours about the safety culture in RP. • It can be used to record the RP safety culture of hospital workers and support organisations in learning to improving it.		
	B6 Tools	Chatzis et al. (2021) Greece	Build an instrument to record beliefs, perceptions and behaviours that reflect the culture of safety in RP					• Sample limited to one hospital • Long questionnaire • Did not show good reliability in the variables of mistakes	High (8/8)
	B7 Diagnosis Tools	Keshtkar and Masoumi, (2021) Iran	Evaluate the knowledge and practice about RP principles	**1.** TR and surgical teams from university and non-university hospitals, and private clinics in different cities **2.** 2021 **3.** 400/82%/328 **4.** NR **5.** M145/F183	**1.** Self-administered questionnaires **2.** NR **3.** Masoumi et al. (2018) **4.** 63 **5.** Not available **6.** Content validity by 10 experts – 7 academics (1 from nuclear medicine, 4 medical physicists, 1 epidemiologist and 1 from occupational health) and 3 staff; Reliability analysis (test-retest, Pearson correlation coefficient r=0.81 in pilot study (n=20) (staff radiology) **7.** NR	Knowledge • Basic principles of RP (ALARA) • Annual dose limit and the rule of the 10 days Performance in RP implementation • Attitudes and practice – performance in RP implementation	Knowledge • 38% had an approved training course on RP • Workers with a length of service ≤ 15 years had less knowledge than those with >15 years • TR presented greater knowledge about RP principles • Significant correlation between passing training and knowledge Performance in RP implementation • Significant correlation between knowledge and practice	• NR	High (7/8)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes: Categories or Domains/ Dimensions and their indicators/variables	Outcomes: Main results	Limitations	Methodological quality
Identification of studies	B8	Schroderus -Salo et al. (2019)	Develop and test psychometrical-ly	Same study sample (Hirvonen et al., 2019)	**1.** Self-administered questionnaires **2.** Electronically (Webropol) -	Knowledge • Radiation physics, biology and principles	Knowledge • Scale to assess radiation knowledge levels to	• Answer rate • Power analysis (no studies with	High (8/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age ($\bar{x} \pm \sigma$) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes: Categories or Domains/ Dimensions and their indicators/variables	Outcomes: Main results	Limitations	Methodological quality
through citation bases	Tools	_____ Finland	the knowledge self-assessment scale	**1.** NS in the operating theatre, outpatient clinic and cardiology laboratory - 8 hospitals (4 university and 4 central) **2.** 2017 **3.** 1500/17%/252 **4.** 32 ±6 years **5.** M37/F215	Email (through bosses) **3.** Authors **4.** 41 (Pilot) ➔ 33 (Study) **5.** Available **6.** Face and content validity – 9 experts (MD, RT, radiation expert, NS) with CVI = 0.83; Construct validity - by exploratory factor analysis; Internal consistency reliability analysis using Cronbach 's Alpha = 0.98 (pilot n=22) and 0.93-0.96 (study) **7.** Transversal	of radiation use; • RP; • Safe use guidelines.	determine future training needs and identify development goals • Validated for NS exposed to ionizing radiation with the potential to be used in educational, clinical and research environments	similar scales). • Overvaluation of knowledge by respondents	
B9 Diagnosis	Tools	Kahkhaei and Sarani (2020) _____ Iran	Determine RP knowledge and performance	**1.** Surgical technicians -Zahedan University Hospitals **2.** 2019 **3.** NR/NR/80 **4.** 31 ±7 years old **5.** M34/F66	**1.** Self-administered questionnaires **2.** Manuscript – by hand with integrity monitoring **3.** Authors **4.** 21 questions (knowledge) + 26 observation checklist (performance) **5.** Not available **6.** Content validity – experts; Internal consistency reliability analysis - Cronbach 's Alpha = 0.86 **7.** Transversal descriptive	Knowledge • Training • Assessment of scientific knowledge – right/wrong answers	Knowledge • 7 % had training in RP • They found that age had a directly proportional relationship with knowledge and performance. • They found that professional experience had a directly proportional relationship with knowledge and performance. • The knowledge score was higher in men and the performance score was higher in women.	• NR	High (8/8)
B10	Tools	Mohebbi et al (2021) _____ Iran	Develop a psychometric RP capability questionnaire	**1.** Operating theatre NS **2.** NR **3.** NR/NR/200 **4.** 33 ± 8 years **5.** M111/F88	**1.** Self-administered questionnaires **2.** Manuscript – in hand with integrity monitoring **3.** Authors **4.** 120 qualitative pre-validity ➔63 quantitative pre-validity ➔40 qualitative pre-validity ➔32 **5.** Available **6.** Face Validity – qualitative by 6 experts and quantitative by 6 experts (conceptual and psychometric) + 6 operating theatre NS; Content validity – 8 specialists in nursing, psychometrics, radiology and nuclear	Capability • Knowledge – Radiation physics and radiation biology, protection and safety guidelines (10 items). • Attitude (7 items) • Practice (10 items) • Professional commitments (5 items)	Capability • Valid and reliable instrument that can comprehensively assess the RP capability of operating theatre NS • It can be used in the development of programmes to solve RP problems in operating theatres • Using this questionnaire, it is possible to estimate educational and management needs	• Different exposure conditions between operating theatres	High (8/8)

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Table 2 (*continued*)

Coding	Groups	Author, (Year of publication), Country	Objective	Characteristics of the Sample/population: **1.** Target population; **2.** Year of data extraction **3.** Sample (Sample/ Ratio/ final sample); **4.** Age (x¯± σ) **5.** Genre (Male/Female)	Data extraction and instrument: **1.** Method of data extraction **2.** Means of data extraction **3.** Instrument – origin **4.** Instrument – items **5.** Instrument – access **6.** Instrument - validity and reliability **7.** Type of study	Outcomes		Limitations	Methodological quality
						Categories or Domains/ Dimensions and their indicators/variables	**Main results**		
					medicine by CVI and CVR (0.83); Construct validity – Analysis of main components; Reliability analysis – test-retest and internal consistency reliability by Cronbach 's Alpha =0.82 **7.** Transversal				

Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index; CVR = Content validity ratio.
A1-A13 - Identification of studies through databases, search engines and library databases.
B1-B10 - Identification of studies by manual search; Diagnosis – assessment the population/sample; Intervention – assessment Intervention; Tools - identifies measures for improvement or constructing and validating an evaluation tool to promote improvement.
Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).
Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index; CVR = Content validity ratio.
A1-A13 - Identification of studies through databases, search engines and library databases.
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Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index; CVR = Content validity ratio.
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Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index; CVR = Content validity ratio.
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A1-A13 - Identification of studies through databases, search engines and library databases.
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Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).
Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index; CVR = Content validity ratio;
A1-A13 - Identification of studies through databases, search engines and library databases; B1-B10 - Identification of studies by manual search; Diagnosis – assessment the population/sample; Intervention – assessment Intervention; Tools - identifies measures for improvement or constructing and validating an evaluation tool to promote improvement.
Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).
Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index;

CVR = Content validity ratio.
A1-A13 - Identification of studies through databases, search engines and library databases.
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Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).
Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index;
CVR = Content validity ratio.
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Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).
Notes: NR = No reference; PPE = Personal protective equipment; CPE = Collective protective equipment; RP = Radiation Protection; NS = Nurses; RT= Radiology Technicians; MD = Doctors; CVI = content validity index;
CVR = Content validity ratio.
A1-A13 - Identification of studies through databases, search engines and library databases.
B1-B10 - Identification of studies by manual search; Diagnosis – assessment the population/sample; Intervention – assessment Intervention; Tools - identifies measures for improvement or constructing and validating an evaluation tool to promote improvement.
Methodological quality of the studies through Joanna Briggs Institute checklist for analytical cross-sectional studies – High (7-8); Methodological quality – moderate (4-6); Methodological quality – low (0-3).

warning signs on the room door, and perception of safe practices.

Perceived disease risk assessment included indicators such as concern about radiation, occurrence of occupational diseases among oneself or colleagues, risk of developing cataracts, and vulnerability to adverse effects.

Researchers evaluated worry levels and depressive symptoms using two scales: the general psychological distress scale to assess worry degree, and the Center for Epidemiologic Studies Depression Scale to assess depressive symptoms.

In the studies by Chatzis et al. (2021) and Goula et al. (2021), indicators related to occupational assessed safety and health were assessed. These included satisfaction with the availability of protective equipment, cleaning and disinfection; compliance with guidelines for storing protective; frequency of damage checked; and equipment availability. In the attitude dimension, negative attitude towards protective equipment were assessed. In the feelings and symptoms dimension, negative emotions due to accidental exposure, fear and anger from unintentional exposure, guilt for unintentionally exposed, and psychosomatic symptoms related to negative radiation-related feeling were assessed. In the misconceptions dimensions, beliefs about radiation, RP safety and the importance and necessity of RP were evaluated.

In Roy et al. (2021), indicators assessed in the improvement measures included belief in the effectiveness of strict measures and the impact of appropriate training and health promotion approaches.

In Keshtkar and Masoumi (2021), the performance aimed to assess the correlation between knowledge and practice in RP implementation.

In Mohebbi (2021), the capability dimension aimed to evaluate knowledge (radiation physics and radiation biology, protection and safety guidelines), attitude, practice, and professional commitment.

3.4. Outcomes of included studies - tools

The studies primarily highlighted the implementation of training programmes as the main approach (61%, $n = 14$), suggesting training at academic and hospital levels, both for initial and/or continuing education. Additionally, measures to enhance awareness were recognized, including suggestions for new and efficient methods of raising awareness of risks and conducting workshops (30%, $n = 7$). The use of instruments to identify gaps, support learning through training, and develop programmes for problem-solving, along with estimating educational and management radiation safety, constituted the third category (13%, $n = 3$) (Table 3).

3.5. Outcomes of included studies - diagnosis

Dosimeters usage was evaluated in 12 studies (52%). Among these, 11 (92%) assessed compliance with passive whole-body dosimeters, with usage ranging from 5% (Chow et al., 2013) to 98% (D'Avino et al., 2019). Compliance was below 50% in 5 studies and above 50% in 6 studies. Active dosimeter usage (real-time) was investigated in only 2 (18%) studies, with Fan et al. (2017) reporting 11% usage and Brun et al. (2018) reporting 18%. D'Avino et al. (2019) noted that 6% of individuals used an eye lens dosimeter, and 16% used extremity dosimeters, which were not mentioned in any other studies (8%).

Fifteen articles (65%) evaluated compliance with PPE usage. The lead apron or skirt/coat was the most commonly used PPE in all studies except Marinskis et al. (2013), where the thyroid shield was employed by 94% compared to 98%. Compliance with lead apron or skirt/coat usage ranged from 28% (Fan et al., 2017) to 99% (Friedman et al., 2013), falling below 50% in studies by Barbosa and da Silva (2022) (49%) and Shafiee et al. (2020) (42%). Usage of thyroid shields varied widely, from 15% (Roy et al., 2021) to 98% (Marinskis et al., 2013), with 9 studies below 50% and 7 studies above. Kaplan et al. (2018) reported separate rates for standard and mini C-arms, with 63% using a thyroid shield with the standard and 42% with mini C-arm. Lead glasses usage was examined in 10 studies, with compliance ranging from 0% (Roy

Table 3
Outcomes of included studies - Tools.

Tools	Studies																				Total (%)
	Alshabi et al. (2022)	Barbosa & Silva (2022)	Brun et al. (2018)	Chatzis et al. (2021)	Chow et al. (2013)	D'Avino et al. (2019)	Fan et al. (2017)	Friedman et al. (2013)	Goula et al. (2021)	Hirvonen et al. (2019)	Kahkhaei and Sarani (2020)	Kaplan et al. (2018)	Keshtkar and Masoumi (2021)	Mohebbi et al. (2021)	Mzoughi et al. (2021)	Roy et al. (2021)	Schroderus-Salo et al. (2019)	Shafiee et al. (2020)	Tok et al. (2015)	Van Papendorp et al. (2020)	Walsh et al. (2019)	
Implementation of training programmes - training at academic and/or hospital (initial and/or continuing)	X	X			X	X	X	X	X	X			X		X			X	X	X	X	61%
Modification of training strategies			X																			4%
RP manager in cardiology department to ensure the application of RP standards															X							4%
Action plan in the event of accidents															X							4%
Incidents registration															X							4%
Mandatory periodic monitoring															X							4%
Measures to increase awareness (e.g. workshops)	X		X			X		X		X	X	X										30%
Improve access to protective equipment (e.g. lead glasses and collective protective equipment)			X					x														9%
Use of dosimeters and determination of exposure levels by the authorities																			X			4%
Guidelines for establishing strict rules on occupational radiation																X						4%
Associations and organizations should collaborate to propose regulations																X						4%
Promotion and recommendation of health promotional videos, lectures and practical strategies																X						4%
Encouraging radiation safety education with additional provisions for pregnant interns								X														4%

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Table 3 (*continued*)

Tools	Studies																					Total (%)
	Alshabi et al. (2022)	Barbosa & Silva et al. (2022)	Brun et al. (2018)	Chatzis et al. (2021)	Chow et al. (2013)	D'Avino et al. (2019)	Fan et al. (2017)	Friedman et al. (2013)	Goula et al. (2021)	Hirvonen et al. (2019)	Kahkhaei and Sarani (2020)	Kaplan et al. (2018)	Keshtkar and Masoumi (2021)	Mohebbi et al. (2021)	Mzoughi et al. (2021)	Roy et al. (2021)	Schroderus-Salo et al. (2019)	Shafiee et al. (2020)	Tok et al. (2015)	Van Papendorp et al. (2020)	Walsh et al. (2019)	
Use of instruments to identify gaps, support learning through training, develop of programmes for solving problem, estimating educational and management radiation safety				X										X			X					13%
A proposal for a dedicated fund to acquire sufficient protective equipment should be submitted to the government or relevant organizations																x						4%

et al., 2021) to 89% (Marinskis et al., 2013), with unavailability noted in van van Papendorp et al. (2020). Gloves usage was examined in 5 studies, with compliance ranging from 0% (Roy et al., 2021) to 32% (Marinskis et al., 2013) and unavailability noted in van van Papendorp et al. (2020).

Five studies examined additional protective measures, including Collective Protective Equipment (CPE) such as lead glass walls, table shields, sterile radiation-absorbing pads, ceiling shields, and mobile shields, as well as PPE like gonadal protection. According to Marinskis et al. (2013), 84% of respondents reported using a lead glass wall, 71% used a shielded table, 27% used sterile radiation-absorbing pads, and 19% used a mobile radiation protection cabinet. Brun et al. (2018) found that none of the respondents used CPE. Fan et al. (2017) reported that 35% of respondents used mobile shielding. Roy et al. (2021) found that none of the respondents used gonadal protection. van Papendorp et al. (2020) noted that mobile, table, and ceiling shields were unavailable. Reasons for not using PPE included discomfort, lack of equipment, difficulty or impracticality of the procedure, existing CPE, unawareness of the risk, and not knowing where to purchase the equipment (Roy et al., 2021; Goula et al., 2021; van Papendorp et al., 2020; Barbosa and da Silva, 2022; Chow et al., 2013).

The frequency of education or training was varied across 9 studies, ranging from 7% to 69%. Mzoughi et al. (2021) reported the highest percentage, with 69% of participants having received RP training, Barbosa and da Silva (2022) reported 19%, Brun et al. (2018) reported 13%, and Kahkhaei and Sarani (2020) reported 7%. Alshabi et al. (2022) found that 11% of participants had received RP training, while 33% had undergone training specifically on fluoroscopy equipment. Shafiee et al. (2020) discovered that 27% of nurses and 66% of doctors had undergone RP courses/training. Tok et al. (2015) reported that 89% had information on radiation's harmful effects, with 44% having received formal training. Friedman et al. (2013) mentioned that 55% had completed mandatory postgraduate training, and 58% had received department or service training. Keshtkar and Masoumi (2021) reported that 38% had completed an approved training course.

Mzoughi et al. (2021) reported 0% knowledge regarding the eye lens dose limit, contrasting with D'Avino et al. (2019) finding of 19%. Roy et al. (2021) assessed knowledge at 63%, deemed adequate. Barbosa and da Silva (2022) found only 77% were aware of X-radiation from radiological equipment. Brun et al. (2018) noted 13% recognized their insufficient knowledge, while Friedman et al. (2013) reported that 53% felt adequately trained. Fan et al. (2017) observed 43% possessed good radiation knowledge. Hirvonen et al. (2019) scored knowledge on a 10-point scale, ranging from 3.8 to 6.5. van Papendorp et al. (2020) noted limited knowledge: 23% understood the ALARA principle, 20% identified the annual dose limit, 70% defined the inverse square law correctly, 61% understood the impact of reducing patient on worker dose, 64% knew about shielding equipment efficacy, 50% mistakenly believed closer proximity to the source offered better protection. Goula et al. (2021) found satisfactory knowledge on individual dosimetry but inadequate understanding of general, basic, and advanced RP. Less experienced workers had a higher level of knowledge.

3.6. *Outcomes of included studies - intervention*

Walsh et al. (2019) assessed the impact of an educational lecture and found that while participants valued it, there was no statistically significant improvement in knowledge levels. This underscores the necessity for comprehensive RO training programmes to realize meaningful benefits. In contrast, Brun et al. (2018) evaluated a one-day training session and noted participants perceived enhanced knowledge, with, and a significant increase observed in knowledge levels. However, the training had failed to translate into improved compliance with RP practices, emphasizing the inadequacy of single-session interventions. The study underscores the imperative to refine RP training strategies and foster awareness of radiological risks and RP safety protocols.

4. Discussion

Countries like Saudi Arabia, Turkey, Argentina, USA, France, Greece, Finland, and Canada boast a very high Human Development Index (HDI). Conversely, Tunisia, Iran, Brazil, South Africa, and China have a high HDI, while India falls under medium HDI (United Nations Development Programme, 2022). This distinction is crucial when comparing studies.

Among studies that assessed the frequency of education or training, the highest value was found in a country with a very high HDI, while the lowest was observed in a high HDI country. Similarly, both the maximum and minimum values for compliance with the use of passive whole-body dosimeters occurred in countries with a very high HDI. For compliance with the use of lead aprons, the maximum value was observed in a country with a very high HDI, while the minimum value was in a high HDI country. Similarly, for compliance with the use of thyroid shields, the maximum value was found in a country with a very high HDI, while the minimum value was observed in a country with medium HDI.

The predominance of studies published in the last 5 years underscores the increasing attention to RP within scientific communities.

Expert panels involved in content validity assessment exhibit diversity in terms of number and expertise, a common observation across literature. Consensus on the ideal number of experts lacks, with varied recommendations (Almanasreh et al., 2019; Belton et al., 2019; Coluci et al., 2015). To ensure accurate and plausible judgments, a heterogeneous panel reflecting diverse perspectives in advised. Selection should prioritize experts with domain knowledge, justifying their classification as 'expert' (Almanasreh et al., 2019; Belton et al., 2019).

Only 33% ($n = 7$) of the instruments in this study demonstrated validity and reliability, with 2 not exclusively for assessing occupational RP. Consequently, only 23% ($n = 5$) of the instruments were valid and reliable for assessing occupational RP, and of these, only 17% ($n = 4$) were accessible. Therefore, there is a scarcity of instruments designed for measuring RP during surgical procedures and/or interventional procedures. This scarcity has also noted by Mohebbi (2021). Validity and reliability are crucial for ensuring trustworthy research outcomes, as they indicate accuracy, precision, consistency, and reproducibility of an instrument (Almanasreh et al., 2019; Schroderus-Salo et al., 2019; Sürücü and Maslakçi, 2020). Thus, it is imperative to evaluate both properties to ensure an instrument's effectiveness (Sürücü and Maslakçi, 2020). The quality of information provided by instruments relies on their psychometric properties, necessitating a thorough understanding by researchers (de Souza et al., 2017).

The dimension/domain most studied in the questionnaires was knowledge, which was addressed in 82% ($n = 19$) of the studies. Education is considered the most important method to implement in order to improve RP (Behzadmehr et al., 2021; Consejo de Seguridad Nuclear, 2017; Kim et al., 2018a, 2018b; Smith et al., 2022), therefore, it makes sense for it to be the most evaluated dimension in the instruments.

The studies that assessing knowledge indicate a lack of training and education, which is in line with other studies in the literature (Alavi et al., 2017; Alyahyawi et al., 2022; Girgin, 2021; Hammami et al., 2021; Hussein et al., 2022; Kim et al., 2018a, 2018b; Söylemez et al., 2013).

The use of passive dosimeters or thyroid protectors and lead aprons or skirts/coats did not reach full compliance due to various challenges such as: resistance and/or lack of PPE and CPE; resistance to the use of dosimeters; lack of knowledge of other RP measures; and the average level of knowledge, which may reflect a lack of RP culture. The average level of knowledge chosen in this study is consistent with the literature, e.g. Behzadmehr et al. (2021), Bartal et al. (2016), Consejo de Seguridad Nuclear (2017).

Some instruments aim to measure limited dimensions, such as knowledge only, as in the studies by Walsh et al. (2019), Hirvonen et al. (2019), Schroderus-Salo et al. (2019) and Kahkhaei and Sarani (2020), but workers with good knowledge may not have good attitudes towards RP (Lewis et al., 2022). Therefore, it is also necessary to accurately assess different areas such as attitudes, behaviours, practices and risk perceptions, which can help to manage policies and procedures, improve awareness and change the attitudes and behaviours of workers.

The variations observed in the utilization of protective equipment and dosimeters among the included studies can be attributed to disparities in methodology, sample size, target population, and country of origin. It is crucial to acknowledge that legal requirements, guidelines, regulations, procedures, practices, and training content may differ across countries, potentially impacting the performance of workers in their daily tasks. Current evidence suggests varying results across different countries regarding RP (Alavi et al., 2017; Alzubaidi et al., 2017; Maas et al., 2021; Ottolenghi et al., 2019; Ploussi et al., 2021; Shanani et al., 2018). Behzadmehr et al. (2021) found varying levels of awareness, attitude, and performance across different countries. Similarly, the EUROMED project Rocc-n-Roll found heterogeneity in compliance with guidelines and the European directive, as well as differing perceptions regarding training and education in RP and a lack of implementation of legislation (Santos et al., 2023).

The study recommends several tools to improve RP in workplaces, which are consistent with the existing literature. These tools include supervision/audits, training and practices in RP through academic training, continuous and mandatory workplace training, and the provision and use of appropriate protective and monitoring equipment (Behzadmehr et al., 2021; Bowman et al., 2018; Consejo de Seguridad Nuclear, 2017; Nugent et al., 2015; Santos et al., 2023).

This study has inherent limitations that must be carefully considered. The inclusion criteria restricted the review to quantitative studies, and all the included studies were cross-sectional. Consequently, when interpreting the results, it is crucial to acknowledge the inherent limitations of this study design and consider the limitations associated with the specific instruments employed. These limitations encompass factors such as sample size, response rate, interpretation bias, the potential for biased and dishonest responses, as well as the validity and reliability of the instruments.

Furthermore, the diversity in instruments used across the studies precluded the possibility of conducting a meta-analysis. The study's sole authorship restricted the capacity for verification and evaluation of the methodological quality of the included studies, introducing the potential for bias. Additionally, the review is constrained by the presence of several studies with a moderate risk of bias and one study with a high risk of bias. Therefore, exercising caution is imperative when analysing the studies and interpreting the results. Recommendations for future research include an emphasis on improving methodological aspects.

5. Conclusions

The global acknowledgment of occupational safety, health, and RP importance is clear. However, there's a need for stronger RP emphasis, as monitoring and protective equipment were not universally utilized. Passive dosimeters, thyroid shields, and lead aprons/skirts/coats were variably used across studies. Among the 23 studies, only 52% ($n = 12$) mentioned the reliability and/or validity of instruments, with a mere 13% ($n = 3$) focusing on development and psychometric testing. Just 23% ($n = 5$) of instruments exclusively evaluated occupational RP with both validity and reliability. Knowledge predominated in 82% of studies ($n = 19$). Limited use of instruments with validated psychometric properties hampers monitoring unsafe behaviours and designing interventions. Developing instruments with validity is recommended to accurately reflect reality. These tools can be instrumental in creating RP problem-solving programmes, assessing training and management needs, and facilitating the diagnosis, comparison, and evaluation of workplace interventions to enhance RP culture. Such tools add value to organizations and employees. The lack of standardized tools also poses challenges in comparing data internally, nationally, and internationally.

Therefore, this systematic review of the literature contributes to the assessment of the state of the art and with inputs for the development of instruments.

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CRediT authorship contribution statement

Sara Videira: Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Matilde Rodrigues:** Writing – review & editing, Validation, Supervision, Methodology. **Manuela V. Silva:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2024.107913.

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