



Review paper

Prevalence of the use of dosimeters for ionizing radiation from fluoroscopy – a systematic literature review and *meta*-analysis

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ABSTRACT

This study aims to assess the prevalence of individual dosimeter use among workers exposed to ionizing radiation during fluoroscopy-guided procedures. Additionally, factors contributing to its use were identified.

Studies were identified through searches in five databases on 13 April 2024. Additionally, snowballing techniques were employed. The review followed PRISMA guidelines and the CoCoPop model. A narrative synthesis, bibliometric analysis, and *meta*-analysis were performed. Study quality was assessed using the Joanna Briggs Institute checklist for prevalence studies.

Fifty studies involving 11,067 individuals were included. Orthopedics/traumatology was the most studied specialty (46 %). Median use rates were: 24 % (IQR = 44 %) for eye lens dosimeters, 15 % (IQR = 13 %) for electronic real-time dosimeters, 27 % (IQR = 42 %) for wrist/finger dosimeters, 25 % (IQR = 23 %) for collar/thyroid dosimeters and 5 % for ankle dosimeter; 15 % (IQR = 78 %) reported no monitoring device. In 15 studies (30 %) with 4,188 individuals (38 %), the overall prevalence of “always” using whole-body dosimeters was 43 % [95 %CI:24–62]. By continent, the highest prevalence was found in Africa (75 % [95 %CI: 46–95]), while the lowest was in the “Americas” (33 % [95 %CI: 16–52]). Significant moderator effects were found: higher prevalence in “Africa” ($p = 0.04$), “gastroenterology” ($p = 0.04$), and “involving radiology” ($p = 0.01$); lower in “orthopedics” ($p = 0.01$) and “physicians” ($p = 0.03$). No significant moderator effects were found: “very high Human Development Index” ($p = 0.72$) and “high Human Development Index” ($p = 0.69$). Studies showed moderate risk of bias (6/9), with little evidence of publication bias.

Exposure doses may be underestimated due to the low prevalence of dosimeter use. Interventions targeting individual and organizational factors are needed to promote consistent use and improve safety.

1. Introduction

The popularity of minimally invasive surgery in various medical specialties due to the benefits they present, technological development,

and ease of access to equipment leads to a significant increase in the use of fluoroscopy [1–4]. Every day, thousands of patients worldwide benefit from the diagnostic and/or therapeutic applications of ionizing radiation through fluoroscopy equipment. There has also been an

Abbreviations: C, confidence interval; CoCoPop, Condition Context Population; HD, Human development index; IQR, interquartile range; IAEA, International Atomic Energy Agency; ICRP, International Commission on Radiological Protection; JB, Joanna Briggs Institute; JIF, Journal Impact Factor; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis; PPE, Personal protective equipment; RP, Radiation protection; SJR, SCImago Journal Rank.

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increasing trend in interventional radiology procedures. In 2020, it was estimated that 24 million procedures were performed ($\pm 80\%$ uncertainty), which corresponded to a six-fold increase in twelve years [5,6], raising growing concerns and new questions in terms of occupational radiation protection (RP) [7].

The estimated annual number of monitored workers exposed to ionizing radiation in the 2010–2014 period was 24 million, which compared to the 1995–1999 period was an increase of 5 % (23 million), with a 14 % increase for workers exposed to human sources (10 vs. 11.4 million), and 80 % corresponding to the medical field [6]. In terms of the average dose of occupational exposure, comparing data from 1980 to 1984 and 1990–1994, it was found that there was a 50 % decrease in the medical field (from 0.6 mSv to 0.3 mSv) and that between 2000–2002 there was a reversal of the downward trend to an upward trend as there was a 67 % increase (from 0.3 mSv to 0.5 mSv) which remained unchanged in the 2010–2014 period (0.5 mSv) [6,8].

There is evidence suggesting an increased risk of cancer and mortality linked to occupational exposure to ionizing radiation [9,10]. Although epidemiological studies have explored the incidence of cancer associated with occupational medical exposure, the findings are limited by methodological issues, especially in establishing clear dose–response relationships and accounting for confounding factors such as lifestyle [11,12]. In older cohorts and due to prolonged exposure, a high risk has been found, but the short follow-up period of current cohorts has not allowed definitive conclusions to be drawn [11]. The myelodysplastic syndrome and lung cancer were significantly higher causes of death compared to the general population [10]. There is concern about the lack of integrity of dosimetry reconstruction, with workers suspected of not using personal dosimeters properly [11]. Lee et al. found an 89 % increase in the dose adjusted by dosimeter use compliance concerning the average annual effective dose (1.79 mSv vs. 0.95 mSv, respectively) [13]. Therefore, epidemiological studies may have biased risk estimates if they only consider dose data from dosimeters [13].

Radiation safety guidelines focus on keeping exposure levels “as low as reasonably achievable” (ALARA) and adhering to established safety limits. Thus, the goal is to create a work environment with minimal radiation exposure, ideally as close to zero [14]. Various technologies are available on the market for personal dosimetry [15]. Dosimeters must be accurate under various exposure conditions, minor, and light enough to be convenient to use without interfering with clinical practice [16]. Although monitoring workers exposed to ionizing radiation is a legal requirement, according to data from the International Atomic Energy Agency (IAEA) in 2014, 76 % of interventional cardiologists reported that they always use a personal dosimeter, differing slightly between developed and developing countries (77 % vs 70 %, respectively) [16,17]. Still, self-reporting may have overestimated dosimeter use [16]. The International Commission on Radiological Protection (ICRP) noted that occupational dose values are often surprisingly low, not due to high RP, but rather the failure to use personal dosimeters—an issue observed worldwide [16,18]. The lack of efficient individual dosimetry for occupational exposure was a problem identified at the Ibero-American conference, resulting from deficiencies in the use of dosimeters, difficulties in accessing individual dosimetry, and the proper use of dosimeters [15]. Therefore, “radiation safety performance is more than simply measuring doses” because doses provide limited information about radiation safety behaviors [19].

This scenario highlights the importance of ensuring radiation safety for healthcare workers [16,20,21]. RP can play a crucial role in the Sustainable Development Goals outlined in the 2030 Agenda, directly or indirectly [22]. This systematic review aims to evaluate the state of the art on the prevalence of the use of dosimeters for workers exposed to ionizing radiation from fluoroscopy equipment in surgical and/or interventional procedures to understand whether or not workers’ exposure is undervalued and identify factors. To our knowledge, no study has been carried out with this objective.

2. Methods

This systematic review was based on the precepts established by the PRISMA model – Preferred Reporting Items for Systematic Reviews and Meta-Analysis [23]. The protocol was registered in PROSPERO (CRD42024597381).

2.1. Research question and eligibility criteria

The research was based on the following question: What is the prevalence of using individual monitoring dosimeters among workers exposed to ionizing radiation from fluoroscopy equipment in surgical and/or interventional procedures? The study also addresses the following secondary questions: What individual monitoring devices are used? What are the factors behind the lack of use of monitoring devices? What are the workers’ characteristics and the bibliometric characteristics of the studies?

Eligibility criteria were defined according to the modified PICO strategic model, using the acronym CoCoPop: Condition (Co), Context (Co), and Population (Pop) [24–26]. Therefore, inclusion and exclusion criteria were established and are detailed in Table 1. The studies had to include data on the prevalence of dosimeter use, obtained using a questionnaire (Co) among healthcare workers exposed to ionizing radiation from fluoroscopy equipment (Pop) in operating rooms and/or interventional rooms (Co). Additionally, only original quantitative studies published since 2018 in peer-reviewed journals and written in Portuguese, Spanish, English, and French (Table 1). A time limit was set because the ICRP published recommendations in 2007 [27] that were considered in Directive 2013/59/EURATOM. Member States had to put into force the necessary legislative, regulatory, and administrative provisions to comply with this directive by 6 February 2018 [28] and the IAEA’s Basic Safety Standards, which were updated and published in 2014 [29].

2.2. Information sources

In the first phase, author 1 identified studies using five databases and revised them by author 2: MEDLINE through PubMed, Academic Search Complete through EBSCOHost, Scopus, Web of Science Core Collection, and ScienceDirect. The search was carried out on 13 April 2024. In the second phase, manual methods were used to identify studies using the snowballing technique. The title of the article considered included in the first phase was searched in Scopus (preferably) to identify citations (forward snowball) and bibliographic references (backward snowball). News articles were identified through back-and-forth snowballing based on the initial set and were done for all articles meeting the inclusion

Table 1
Eligibility criteria.

CoCoPop	Inclusion criteria	Exclusion criteria
Condition (Co)	- Prevalence of use of dosimeters - Research instrument – questionnaire	- Other research instruments
Context (Co)	- Work context – operating and/or interventional rooms with fluoroscopy equipment	- Other work contexts
Population (Pop)	- Human healthcare workers - Exposure to ionizing radiation from fluoroscopy equipment	- Workers in other areas (e.g., veterinary, industry) - Radiation from other equipment
Others	- Quantitative studies - Publication since 2018 - Language – English, French, Spanish or Portuguese - Original research articles in peer-reviewed journals	- Qualitative studies - Publication before 2018 - Language – other languages - Reviews articles

criteria. The search was limited to articles published since 2018. To have traceability, the process was recorded in a table [30,31].

2.3. Search strategy

An advanced search was carried out in the databases using Boolean operators and special characters to improve the search strategy through different combinations. The keywords were determined based on medical subject headings (MeSH), keywords from relevant studies, and professional experience, and adapted to the specificities of the databases. The keywords used in the database search were: “dosimeter*”, “monitoring device*”, “fluoroscopy”, “c-arm*”, “image intensifier”, “questionnaire*”, “survey*”, and “self-report*”. The search had a temporal limit since 2018 and was restricted to document type (articles) in Scopus and ScienceDirect and peer-reviewed scientific journals in Academic Search Complete (Appendix A).

2.4. Selection process

The articles were managed systematically using Rayyan [32]. The selection process involved three distinct phases: 1- Duplicate studies were identified and removed using Rayyan, with double-checking in Zotero; 2- The titles and abstracts of articles were evaluated in Rayyan and categorized as either “include,” “exclude” or “maybe”; 3- Full texts of articles deemed relevant and previously categorized as “include” and “maybe” were thoroughly read. Articles were once again classified as “include” or “exclude” in Rayyan, with explicit documentation of the reasons for exclusion. The first author carried out this process, and the second reviewed it.

2.5. Data extraction

The data extraction process encompassed a comprehensive review of each selected article, with the detailed organization in Microsoft Excel spreadsheets capturing essential and pertinent information for this study. Information on the characteristics of the studies (author(s), year of publication, objective, type of study, and country), sample/population details (target population, sample size, response rate, age, and sex distribution), data collection process (validity and reliability of the instrument, the year/duration of the study, and the study design). Analysis of the results of variables related to the dosimeter device used and its prevalence, identification of factors limiting its use, whether they have received training/education about fluoroscopy or radiation safety, and whether they know the values of dose records. The limitations of the studies were documented. To analyze the prevalence of data extracted from the diagnostic questionnaire. The first author carried out this process.

2.6. Data synthesis

Due to the methodological diversity of the articles, a narrative synthesis approach was employed to summarize the findings [33]. A direct and indirect extraction of data and a statistical analysis were carried out. The studies were analyzed by type of dosimeter and scales of use (yes/no – we know they use it, but it may not mean they always use it) and frequency of use ($\geq 50\%$ of the time; always; never; $< 50\%$ of the time; $> 75\%$ of the time) to align with the scales used in the questionnaires. The Human Development Index (HDI) of the country where the study was conducted was identified according to the four categories proposed by the United Nations Development Program in 2024: very high, high, medium, and low HDI [34]. A bibliometric analysis was performed to map literature trends and create indicators for information and knowledge management, enabling the measurement of scientific activities and the assessment of the relationship between scientific and technological advancements [35]. The software used for the analysis was VOSviewer version 1.6.19 [36]. The protective equipment was divided into two

categories: personal and collective.

2.7. Statistical analysis

Descriptive statistics were performed using Microsoft Excel from Office Professional Plus 2021, and meta-analysis was conducted using the meta package (version 8.0–1) in RStudio software (version 4.4.0). Descriptive statistics were presented as mean $\pm$ standard deviation, median (interquartile range – IQR), and (minimum–maximum). Due to high heterogeneity between studies, a random-effects model was fitted using Restricted Maximum Likelihood estimation with the Hartung-Knapp-Sidik-Jonkman adjustment [37]. Prevalence and variance estimates were derived using an arcsine transformation. A correction of 0.5 was applied when the number of correct answers was 0 or equal to the sample size. Declarations of conflict of interest and support were analyzed to assess the reporting bias. Publication bias was assessed using funnel plot analysis for more than 10 studies [38] along with Egger and Rank correlation tests. The trim-and-fill method corrects publication bias and validates conclusions [39]. Heterogeneity among studies was assessed using Cochran’s Q test and the I² statistic. The thresholds to interpret I² values were: 0 % to 40 % may not be important; 30 % to 60 % may represent moderate heterogeneity; 50 % to 90 % may represent substantial heterogeneity; from 75 % to 100 % considerable heterogeneity [40,41]. The outcomes extracted from each study included in the meta-analysis were the prevalence of dosimeter use, consistently defined as “always”. A sensitivity analysis was conducted to assess the impact of low-quality studies on the overall results. Heterogeneity was investigated through subgroup analysis. The minimum number of studies per subgroup was two [42]. A p-value of less than 0.05 is considered statistically significant.

2.8. Quality appraisal

To evaluate bias in selected studies, the JBI critical appraisal checklist for studies reporting prevalence data comprises nine questions. It was chosen because it was considered the most suitable for this type of study [24,43]. The quality assessment tool is intended to evaluate the risk of the target population, recruitment processes, sample size, description of subjects and the setting, methods used for the identification, sufficient coverage of the identified sample, the response rate, and other biases [26,44,45]. The first author evaluated each item, and the second revised. Each item had ‘yes,’ ‘no,’ ‘unclear,’ or ‘not/applicable’ options. The studies’ methodological quality was then categorized as low risk of bias (7–9 ‘yes’ – [78 %–100 %]), moderate risk of bias (4–6 ‘yes’ – [34 %–77 %]), or high risk of bias (0–3 ‘yes’ – [0 %–33 %]). Therefore, methodological quality was then categorized as “Low” if up to three “Yes” responses were obtained, “Moderate” if six “Yes” responses were achieved, and “High” if seven or more “Yes” answers were reached. Only items with a “Yes” response were considered, while “No”, “Uncertain”, and “Not Applicable” answers were used solely for classification [26,46]. Based on the quality score, studies were not excluded to improve transparency and ensure that available data were reported.

3. Results

A total of 1,528 records were identified by the search strategies in the five databases. In the first phase, filters were applied to the search fields, excluding 1,153 records (Appendix B). Next, 80 duplicates were manually removed, resulting in 295 records. In the title and abstract analysis phase, 242 that did not meet the eligibility criteria were excluded, and 53 reports were subjected to full-text analysis. In the following phase, the full-text analysis of the reports revealed that 36 reports met the eligibility criteria and 17 reports were excluded that did not meet our inclusion criteria. For studies identified by the snowball method, a manual search of references and records citing the included articles from databases yielded 1,584 records, which, when filtered for

publication since 2018, yielded 498 records for title and abstract analysis. Of these, 361 records were excluded, leaving 137 reports for full-text analysis. Still, 109 reports were excluded due to duplicate articles ($n = 102$), eligible language ($n = 4$), and lack of access ($n = 3$). Eligibility criteria were assessed in 28 reports, with 14 reports excluded. Therefore, the snowball search yielded 14 articles (Appendix C). A total of 50 studies were included in this review [13,47–95]. The flowchart of the search, screening, and study exclusion results is shown in Fig. 1. The studies included in the full-text screening and the reasons for their exclusion are listed in Appendices D–F.

3.1. Bibliometric analysis

The 50 studies included were published between 2018 and 2024. Of these, 62 % ($n = 31$) were published between 2021 and 2024. There was a peak in 2021 with 14 publications (28 %) (Appendix G).

The included studies had 266 citations, 69 % ($n = 184$) of which originated from the database. Eight studies with 10 or more citations (16 %) were published between 2018 and 2020. Five (10 %) were identified through database searching, while the remaining three were identified through snowballing. The most cited studies were Sethi et al. [95] from the database with 19 citations and Domienik-Andrzejewska et al. [58] from snowballing with 20 citations. Of the 50 studies included, 71 % of the references were drawn from the database. Wan et al. [92] had the study with the most references (5 %, $n = 65$) (Appendices D and F).

The journal that published the greatest number of studies was the Journal of Radiological Protection ($n = 4$; 8 %). The SCImago Journal Rank (SJR) was located between the quartile (Q1–Q2) in 44 % ($n = 22$) of the studies, while the Journal Impact Factor (JIF) was located in 8 %

($n = 4$). Only 8 % of the studies were located in Q1–Q2 in both cases. However, no data were obtained from 18 % ($n = 9$) and 50 % ($n = 25$) of the studies (SJR and JIF, respectively). In the snowball studies, the SJR was located between Q1–Q2 in 6 % ($n = 3$) of the studies and the JIF in 2 % ($n = 1$). Additionally, the SJR was located between Q2–Q3 in 12 % ($n = 6$) of the studies, and the JIF in 10 % ($n = 5$), but no information was obtained from 10 % ($n = 5$) and 16 % ($n = 8$) (SJR and JIF, respectively) (Appendix H).

It was found that 318 authors were distributed across 46 clusters. Collaboration networks between different clusters were identified with the contribution of 29 authors, with 2 publications included in this review (visualized as larger balls), the maximum number of publications per author. The maximum number of authors per article was 29 [66,67], and the minimum was 1 [64] (Appendix I).

3.2. General characteristics of the included studies

The primary objective of this systematic literature review is to present the outcomes of the studies covered in Appendix J, and the main characteristics of the studies are included to answer the research question in the best possible way.

3.2.1. Characteristics of the sample

In total, 11,067 individuals were included in this review. The median of the study sample size was 146 (IQR = 205), ranging from 10 [13,62] to 989. The median response rate was reported in 56 % (IQR = 56 %) of the 36 studies (72 %), with 6,963 individuals included, corresponding to 63 % of all individuals, and ranged from 8–100 %. The sample distribution by sex was reported in 31 studies (62 %) and included 7,075 individuals (64 %). Most of those who answered the question were male

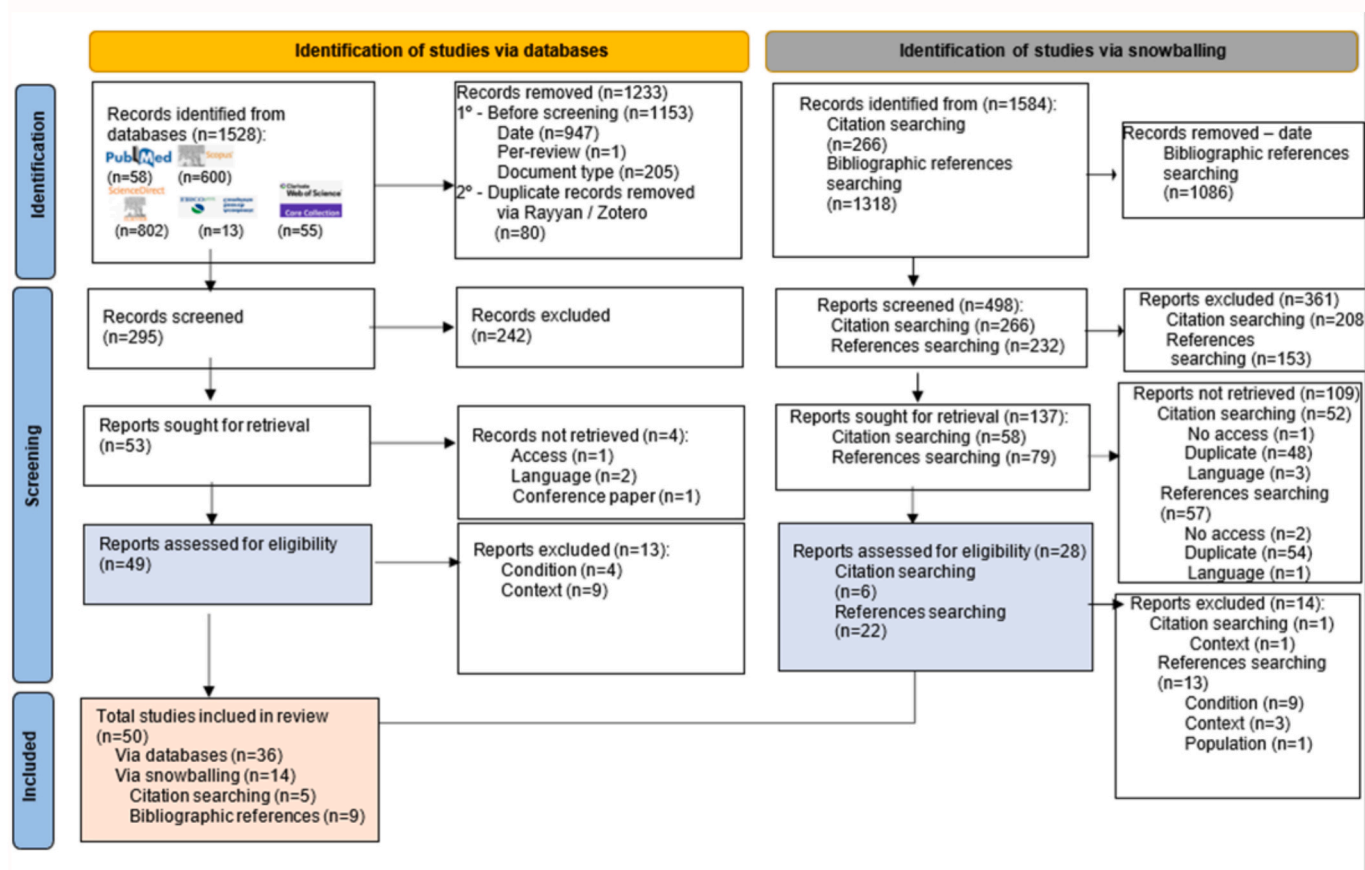


Fig. 1. Flow diagram according to the PRIMA methodology.

(72 %; $n = 5,129$).

The average age and age range of the individuals taking part in the studies were mentioned in 52 % of the studies ($n = 26$), and, of these, 77 % ($n = 20$), the average and age range within the interval, covering the majority of individuals, were between 30 and 50 years old.

In all the studies, physicians were evaluated, including 9,626 individuals (87 %). Different groups of professions were included in 9 studies (18 %), including 950 nurses (9 %) and 460 technicians or technologists (4 %) (e.g. cardiorespiratory technicians, radiology technicians, radiographers, and urotechnicians), and 2 studies ($n = 4$ %), including 31 (0.3 %) other workers (operating room staff and others not specified).

The medical specialties included were orthopedics/traumatology (44 %; $n = 22$), radiology (18 %; $n = 9$), cardiology (18 %; $n = 9$), urology (20 %; $n = 10$), anesthesiology (6 %; $n = 3$), vascular surgery (4 %; $n = 2$), gastroenterology (10 %; $n = 5$), neurosurgery (4 %; $n = 2$), other specialties (e.g., rehabilitation, pediatrics, nephrology or not specified) (6 %; $n = 3$) and surgeons without specifying the specialty (2 %; $n = 1$). Multiple medical specialties were included in 8 studies (16 %) (Appendix K).

All the studies were conducted in various countries worldwide. Of these, 43 studies (86 %) were conducted in a single country, encompassing 8,933 individuals (81 %). The remaining included more than 1 country were grouped into 7 different groups based on the country or region in which they were conducted. The three countries that contributed the most prevalence data to this study were the United States of America ($n = 1,873$; 17 %), South Korea (1,502; 14 %), and Japan (1,157; 11 %) (Appendix L). When analyzing the distribution of countries/regions where the studies were carried out, it was found that individuals from the European continent ($n = 1,956$; 18 %) were included in 11 studies (22 %), from the Asian continent ($n = 4,163$; 38 %) in 21 studies (42 %), from the African continent ($n = 357$; 3 %) in 5 studies (10 %), from the American continent ($n = 2,698$; 24 %) in 8 studies (16 %), from the Intercontinental-Asia/Africa ($n = 793$; 7 %) in 5 studies (10 %) and from more than 1 continent (1,101; 10 %) in 2 studies (2 %). Asia and the Americas were the continents with the largest number of individuals studied. The majority of studies, 32 (64 %), were conducted in countries with a very high HDI and included 7,758 individuals (70 %), the majority of individuals included in this study. In 8 studies (16 %) with 807 individuals (7 %) it was high; in 5 studies (10 %) with 855 individuals (8 %) it was medium; in 1 study (2 %) with 114 individuals (1 %) it was low, and in 4 studies (8 %) it included different countries with different HDIs, or it was not possible to know the HDI because it referred to the continents/regions where the studies were located with 1,533 (14 %).

3.2.2. Characteristics of the data collection

The self-report questionnaire was the most commonly used instrument (98 %; $n = 49$). One study used a visual survey [77]. In 14 studies (28 %) involving 3,387 individuals (31 %), the data collection period was either not mentioned or unclear. Among the studies that report it, data were collected between 2014 and 2022. The period from 2018 to 2022 was the most frequent, appearing in 24 studies (48 %) with 4,478 individuals (41 %). The validity and/or reliability of the instruments were not mentioned or were unclear in 37 studies (74 %). Some form validity was reported in 6 studies (12 %), while 7 studies (14 %) explicitly stated that the instrument has not been validated. The study design was clearly specified in 17 studies (34 %). One study was experimental (trial clinical perspective) [72], while the others were descriptive and/or analytical observational (cross-sectional or longitudinal). Intervention programs were implemented and evaluated in 3 studies (6 %) [55,74,96].

3.3. Individual monitoring dosimeters – devices

The use of whole-body dosimeters was questioned in 98 % of the

studies ($n = 49$), the eye lens dosimeters in 8 % ($n = 4$), the extremity dosimeters for wrists and fingers in 10 % ($n = 5$) and for ankles in 2 % ($n = 1$), the collar/thyroid dosimeters in 6 % ($n = 3$), and the active real-time dosimeters in 6 % ($n = 3$). One study (2 %) analyzed the different possibilities of individual dosimetry [81] (Appendix M).

3.4. Individual monitoring dosimeters – prevalence

A total of 11,005 individuals (99 %) reported using a whole-body dosimeter. In 15 studies (30 %), a median of 38 % (IQR = 48 %) of 4,188 individuals (38 %) used it “always” [13,53,57,66–68,70,73,83,86,87,89,92,93,95]. In 21 studies (42 %), a median of 70 % (IQR = 47 %) of 4,790 individuals (43 %) used it never [49,50,52,54,56,60,68,70,73,80,83,85–93,95].

In ten studies (20 %), 2,193 individuals reported using either always or never using a whole-dosimeter; the median prevalence was 38 % (IQR = 48 %) for always use and 70 % (IQR = 47 %) for never use [68,70,73,83,86,87,89,92,93,95]. In 31 studies (62 %), a median of 43 % (IQR = 46 %) of 5,172 individuals (47 %) reported using it, but it is unclear whether this referred to consistent or “always” use [48–52,54,55,58,59,61–65,68,69,71–79,81–84,88,90–92,94].

In three studies (6 %), a median of 10 % (IQR = 28 %) and 7 % (IQR = 65 %) of 361 individuals (3 %) reported using it ≥ 50 % or < 50 % of the time, respectively [48,73,92]. In one study (2 %), 17 % of 989 individuals (9 %) reported using it > 75 % of the time [13].

In 11 studies (22 %), 1,535 individuals (14 %) reported using a dosimeter under the lead apron [53,55,58,62,63,74,77,81,86,90,94], and in five of these, 1,107 individuals (10 %) used it over the lead apron [58,74,77,90,94]. In four of those studies, a median of 41 % (IQR = 22 %) of 1,077 individuals (10 %) reported using additional dosimetry [58,74,77,94]. One study (2 %) analyzed the correct location of the dosimeter [90].

In four studies (8 %), a median of 24 % (IQR = 44 %) of 337 individuals (3 %) used an eye lens dosimeter [54,62,81,82]. In 5 studies (10 %), a median of 27 % (IQR = 42 %) of 970 individuals used a wrist or finger dosimeter [55,62,81,82,94].

In one study (2 %), 94 % of 62 individuals (0.6 %) always used a collar/thyroid dosimeter, with 81 % placing it under and 19 % over the thyroid shield [47]. In 2 studies (4 %), 25 % (range 8 %–41 %) of 89 individuals (0.8 %) reported using it, but it is unclear whether this referred to consistent or “always” use, nor where they used it [54,81].

In one study (2 %), 5 % of 73 individuals (1 %) reported using an ankle dosimeter [81]. In 3 studies (6 %), a median of 15 % (IQR = 13 %) of 722 individuals (7 %) reported using an electronic real-time dosimeter [55,81,94].

In seven studies (14 %), a median of 15 % (IQR = 78 %) of 1,489 individuals (14 %) reported having no monitoring device [54,57,58,64,76,92,94]. The use of more than two dosimeters was studied in one study (2 %), and 4 % of 570 individuals (5 %) used more than two dosimeters [94] (Fig. 2).

When analyzing the 15 studies evaluating the “always” use of whole-body dosimeters, it was found that the average values ranged from 0–100 %. Of these, three studies (20 %) were carried out solely on the European continent, with values ranging from 26–100 % [53,57,68]; five studies (33 %) were carried out on the Asian continent, with values ranging from 0–74 % [13,66,67,73,92]; three studies (20 %) were carried out solely on the American continent, with values ranging from 22–52 % [83,93,95]; two studies (13 %) were carried out solely on the African continent, with values ranging from 38–87 % [86,89]; one study (7 %) was carried out on several continents and had an average of 21 % [70]; and one study (7 %) was carried out in an intercontinental country (Turkey), with the prevalence of 2 % [87]. Eight studies (53 %) had average values below 50 %, including individuals from countries at all four HDI levels [68,70,73,83,87,89,92,93]. The three lowest average values were 0 % and 2 %, corresponding to countries with a very high HDI (Hong Kong and Turkey, respectively) [87,92], and 6 %, which was

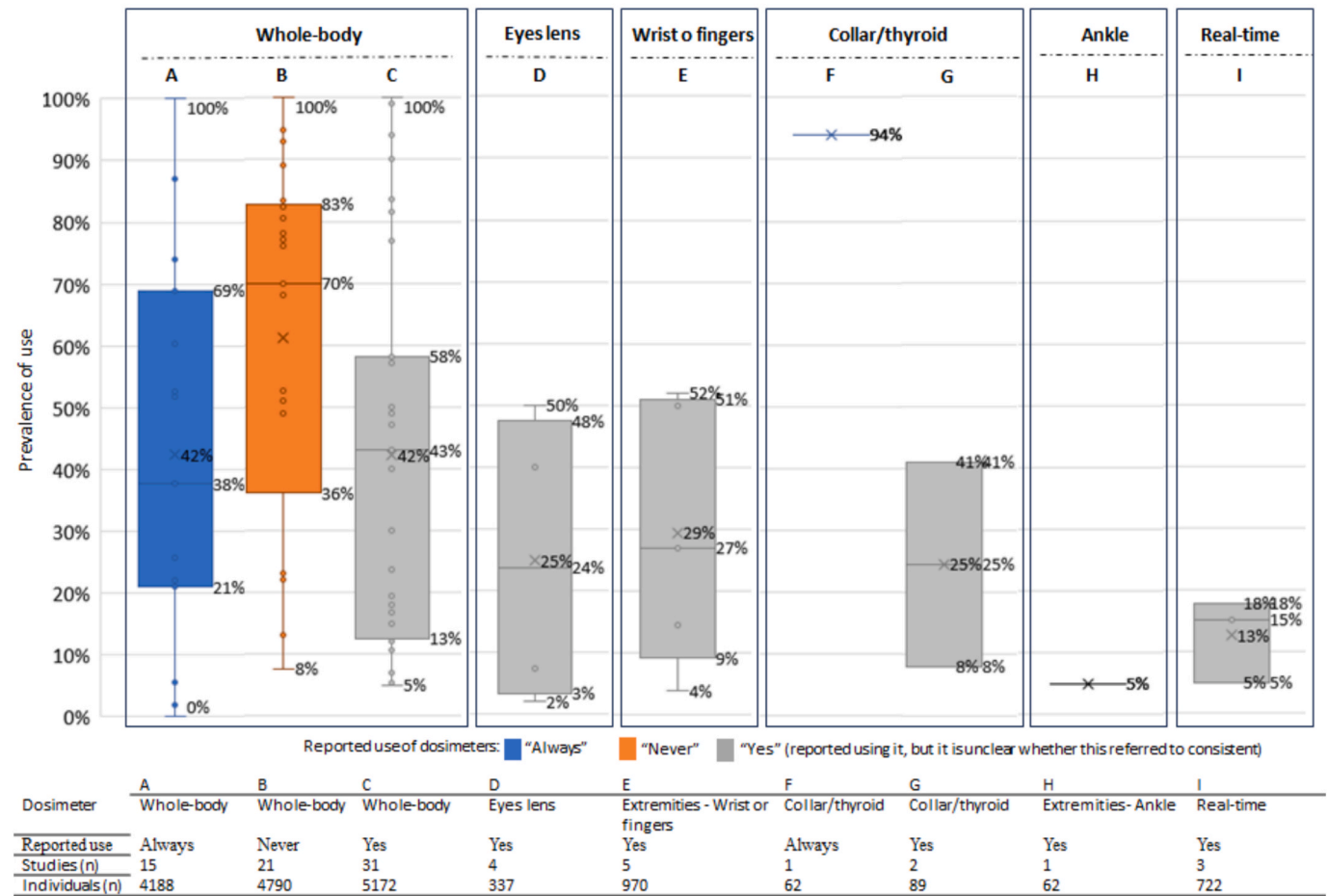


Fig. 2. Box plot of the prevalence of each dosimetry device.

a study carried out in India, which has a medium HDI [73]. Additionally, two studies (25 %) included urologists [68,87], four (50 %) orthopedists [70,73,83,92], one (13 %) interventional cardiologist [89], and one (13 %) anesthesiologist [93].

The use of eye lens dosimeters varied between 2 % and 50 %, all carried out in European countries with a very high HDI [54,62,81,82]. The use of wrist or finger dosimeters ranged from 4-52 % and was carried out in European countries with a very high HDI [55,62,81,82], and one study that also covered other continents and had the lowest value [94]. The dosimeter use in the collar/thyroid ranged from 8 %-41 %, and both studies were carried out in European countries with very high HDI [54,81]. In one study (2 %), carried out in an Asian country with a high HDI, they were asked whether they always used this dosimeter, and the average value was 94 % [47]. The use of an ankle dosimeter was only questioned in one study (2 %), in a European country with a very high HDI [81]. The use of real-time electronic dosimeters ranged from 5 %-18 % and was carried out in European countries with a very high HDI [55,81], and in one study that also covered other continents [94].

Additionally, the eye lens dosimeter was used in two studies (4 %) by urologists [62,82], in one study (2 %) by interventional cardiologists [54], and in another study (2 %) by interventional radiologists [81]. The wrist or finger dosimeter was used by urologists in two studies (4 %) [62,82]. In one study (2 %), which included surgeons and anesthesiologists [55], and in another study (2 %), which included vascular surgeons, cardiologists, and interventional radiologists [94]. The collar/thyroid dosimeter was used in two studies (4 %) by radiologists [47,80] and in one study (2 %) by interventional cardiologists [54]. The ankle

dosimeter was used by interventional radiologists in one study (2 %) [81]. The real-time dosimeter was used in one study (2 %) by interventional radiologists [81], in a study (2 %) that included vascular surgeons, cardiologists, and interventional radiologists [94], and in a study (2 %) that included surgeons and anesthesiologists [55].

3.5. Individual and organizational factors

The factors identified in the studies that may contribute to workers not using personal monitoring devices were: underestimation of the dose of radiation exposure, and underestimation of training on the importance of using a dosimeter was reported in 2 % of the studies [50]; not knowing or not following up on the reports of individual dose readings in seven studies (14 %) [52,59,70,73,86,92,94]; One study (2 %) reported not having enough information about the undesirable effects of radiation, and dosimetric measurements were not carried out regularly [64]; One study (2 %) found that the use of a dosimeter was considered unnecessary by some individuals[69]; 4 % of the studies found that forgetfulness was reported by some individuals [74,91]; not having the monitoring device was mentioned in five studies (10 %) [73,76,77,84,92]; not having a real-time radiation monitor available was addressed in one study (2 %) [94]; the lack of policies enforcing the use of dosimeters and the devices not being readily available in one study (2 %) [75]; and the use of dosimeters not being mandatory in the institution was mentioned in 2 % of the studies [93]. One study (2 %) evaluated the possible relationship between the use of dosimeters and the frequency of fluoroscopy and the concern about radiation exposure,

but the result was not statistically significant [52].

A total of 20 studies (40 %) analyzed training in radiation safety, and 40 % (IQR = 54 %) of 3,902 individuals (35 %) reported having received training [54,56,57,59,63–65,67,68,73,75,76,78,82,84,85,87,89,94,97]. Training in the use of fluoroscopy was analyzed in five studies (10 %), 33 % (IQR = 23 %) of 638 individuals (6 %) reported having received training [52,59,61,95,97].

3.6. Risk of bias assessment

The evaluation of the quality of the included studies is presented in detail in [Appendix N](#). In 100 % of the studies presented, the sample base was appropriate to address the target population. In 84 % of the studies, the study participants were adequately sampled. In 88 % of the studies, the sample size was adequate. Only 48 % of the studies were the study subjects, and the setting described in detail [80,81,83,88,92] did not refer to the age of the individuals included in the study, three studies did not refer to sex [73,87,98], and the remaining 15 studies did not refer to either age or sex. In 74 % of the studies, data analysis was carried out with sufficient coverage of the identified sample. There was a high risk of bias related to the validity and reliability of the instrument used; only 12 % used valid methods, and in 2 %, it was measured in a standard and reliable way. In 100 %, there was an appropriate statistical analysis, and in 74 %, there was an adequate response rate, or it was managed appropriately. Two studies (4 %) had a high risk of bias [59,62], and 32 studies (64 %) had a moderate risk of bias. Overall, the studies had a moderate risk of bias and moderate methodological quality (6/9; 65 %).

3.7. Meta-analysis

The group of dosimeters that met the criteria for the prevalence of dosimeter use, consistently or defined as “always”, for development of the meta-analysis was the whole-body dosimeter ([Fig. 2](#)). The overall combined prevalence of using whole-body dosimeters “always” in 15 studies (30 %) involving 4,188 individuals (38 %) was 43 % [95 % CI: 24 %–62 %]. The included studies in this meta-analysis exhibited considerable heterogeneity ($I^2 = 99\%$, $p < 0.001$). The specificity test was not carried out because no studies with low methodology quality were found 47 % ($n = 7$) were of high quality, and 53 % ($n = 8$) were moderate ([Fig. 3](#)).

Subgroup analysis found that heterogeneity may not be important

only for the cardiology subgroup ($I^2 = 0\%$). In contrast, all other subgroups showed considerable heterogeneity, with I^2 values $\geq 89\%$. Statistically significant moderator effects were observed in specific subgroups: the African continent ($p = 0.04$), medical specialties including orthopedics ($p < 0.01$), gastroenterology ($p = 0.04$), involving radiology ($p = 0.01$), as well as in studies where physicians were the only professional group ($p = 0.03$). The subgroup African continent, gastroenterology, and being involved in radiology subgroups contribute significantly to the increase in overall combined prevalence, and the orthopedics and physicians' subgroups to the decrease. In contrast, no significant effects were found in the subgroups categorized by very high and high HDI, Europe, Asia, Americas, cardiology, and those with high methodological quality. The prevalence rates within these subgroups varied considerably. The African continent subgroup had a prevalence of 75 % [95 % CI: 46–95] compared with 38 % [95 % CI: 19–59] for other continents. The orthopedic subgroup recorded 12 % [95 % CI: 4–24], lower than the other specialties 56 % [95 % CI: 35–76]. On the other hand, gastroenterology had 66 % [95 % CI: 53–78], and the subgroup including radiology had 85 % [95 % CI: 49–100], which is highest than in other specialties 56 % [95 % CI: 35–76] and 32 [95 % CI: 17–49], respectively. The subgroup of physicians only showed a prevalence of 35 % [95 % CI: 14–60], which is lower when including several professions 64 % [95 % CI: 55–73]. Thus, the orthopedic and urologic subgroups had the lowest prevalence rates. In contrast, the subgroup, including radiology, had the highest combined prevalence (as shown in [Table 2](#)).

3.8. Publication bias

The rank correlation test ($p = 0.85$) and Egger's test ($p = 0.42$) indicate no significant evidence of asymmetry in the funnel plot, suggesting no publication bias. However, the Trim-and-fill analysis identified one missing study ([Fig. 4](#)). The overall estimate increases to 47 % [95 % CI: 0.28–0.67], corresponding to a 4 % increase when the study imputed by the trim-and-fill method is included.

It was found that 34 studies (64 %) did not report any conflict of interest, 14 studies (28 %) had no reference, and 2 studies (4 %) were declared but without interference with the study. In 5 studies (10 %), public and corporate support was declared, 22 studies (44 %) did not report any support, and 23 studies (46 %) had no reference, which means that there may be biases in reporting in the studies analyzed.

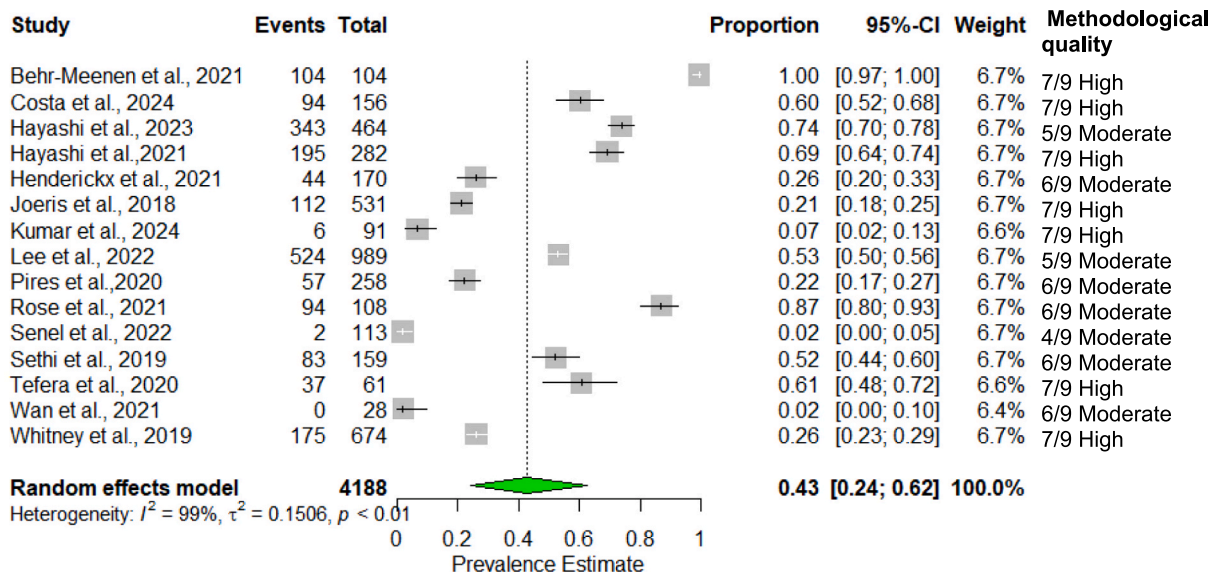


Fig. 3. Forest plot of the combined prevalence of using whole-body dosimeters “always” ($K = 15$).

Table 2
Prevalence of subgroups in this *meta-analysis*.

Question (subgroup)	Yes					No					P-value
	Ns	Ni	Weight (%)	Prevalence (%) [95 % CI]	I ² (%)	Ns	Ni	Weight (%)	Prevalence (%) [95 % IC]	I ² (%)	
HDI – Very high ^a	10	3139	67	45 [21–70]	99	5	1049	33	38 [11–70]	98	0.72
HDI – High ^a	2	366	13	56 [2–99]	99	13	3822	87	41 [21–62]	99	0.69
Europe ^a	3	430	20	68 [17–99]	99	12	3758	80	37 [19–57]	99	0.28
Asia ^a	5	1854	67	37 [8–72]	99	10	2334	33	46 [23–70]	99	0.67
Americas ^a	3	1091	20	33 [16–52]	96	12	3097	80	45 [23–69]	99	0.41
Africa ^a	2	169	13	75 [46–95]	93	13	4019	87	38 [19–59]	99	0.04*
Orthopedics ^a	4	908	27	12 [4–24]	89	11	3280	74	56 [35–76]	99	0.01*
Gastroenterology ^a	3	905	20	66 [53–78]	92	12	3283	80	37 [17–61]	99	0.04*
Cardiology	2	217	13	60 [54–67]	0	13	3971	87	40 [20–63]	99	0.09
Urolog	2	283	13	11 [0–44]	98	13	3905	87	49 [29–69]	99	0.05
Radiology ^b	3	1201	20	85 [49–99]	99	12	2987	80	32 [17–49]	99	0.01*
Physicians ^a	11	2297	73	35 [14–60]	99	4	1891	27	64 [55–73]	96	0.03*
Methodological quality – Hig	7	1899	47	50 [22–79]	99	8	2289	53	36 [14–63]	99	0.49

Note – Ni = number of individuals included; Ns = number of studies included; significant difference; HDI – Human Development Index; CI – confidence interval; ^a – exclusively; ^b – Contains/involving Radiology; * p-value < 0.05 – significant difference; Data in [Appendix O](#).

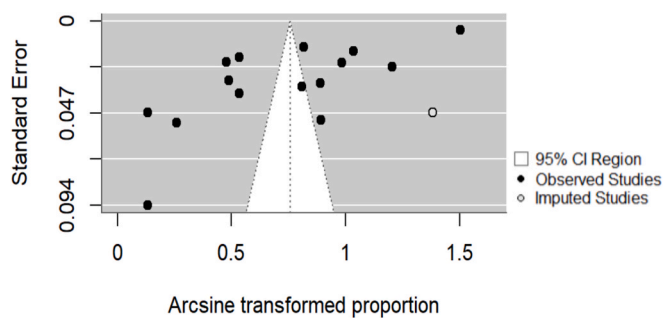


Fig. 4. Funnel plot the analysis prevalence of using whole-body dosimeters “always” (Rank correlation test p-value = 0.85, Egger’s test p-value = 0.42, Trim-and-fill: 1 missing study).

4. Discussion

There is an increasing global awareness of the need to protect workers exposed to fluoroscopy, highlighting the need to create and maintain safe working environments. This concern reflects the importance of mitigating occupational health risks, ensuring adherence to safety protocols, and fostering a culture of proactive protection to safeguard the well-being of these workers [5,6,16,99]. The industry is also developing and introducing new dosimetry devices that provide more accurate and real-time results [100,101].

Descriptive statistics revealed high IQR and wide confidence intervals (CIs) in the overall prevalence of monitoring devices. This variation may stem from methodological differences, such as the research setting configurations, study designs, periods of the studies, and the characteristics of target populations varying by country, legal requirements, policies, and levels of experience in medical specialties, as well as the content of training and education programs affecting safety performance.

It was hypothesized that a lower HDI might correlate with reduced PR literacy levels, poorer working conditions [102], and a weaker culture of PR. In the subgroup analysis of the HDI subgroups studied, the very high HDI subgroup had a higher prevalence than the high HDI subgroup (45 % [95 % IC: 21–70] vs 56 [95 % IC: 2–100], respectively), but the difference in the number of individuals included in the high HDI subgroup was 8.6 times less, but both subgroups had no significant moderation. However, the heterogeneity is considerable; several factors could be confounding, such as the subgroup representing different professions from different medical specialties, different study designs, etc.

A high level of heterogeneity was observed between studies, even in most of the subgroup analyses, suggesting that contextual factors, such as environmental, procedural, or population differences, may influence dosimeter usage and are not captured in the *meta-analysis*. In the literature, there was also a reference to a large variation regarding using passive dosimeters, which aligns with our results. Matsuzaki et al. [74] found that varied between 17 %–100 %, and Videira et al. [102] between 5 % and 98 %.

When we analyzed the subgroups by specialty, there was considerable heterogeneity in the orthopedics and gastroenterology subgroups, and less than half of the overall combined prevalence values (12 % [95 % IC: 4–24] vs. 66 % [95 % IC: 53–78], respectively) involving similar numbers of individuals (908 vs. 905, respectively). Gastroenterology and involving radiology had a statistically significant positive effect on the *meta-analysis* results, and orthopedics was negative. The subgroup of orthopedics and urology had a close prevalence (12 % [95 % IC: 4–24] and 11 % [95 % IC: 0–44], respectively). However, orthopedics contributes significantly, and urology does not, possibly due to the difference in the number of individuals included; orthopedics has 3.2 times more than urology.

Considering that cardiology, gastroenterology, and radiology are specialties that perform interventional procedures, and urology and orthopedics perform surgical procedures, we can say that interventional measures in RP should be intensified in surgical specialties since they have a global prevalence between less than 50 % (11–12 %) and interventional specialties over 50 % (60–85 %). The subgroup that includes radiology had a higher overall prevalence, possibly because these professionals have more protective education and training than other specialties [13,103,104]. Therefore, medical specialization is a factor to consider and may mean that workers in some specialties need more education and training. In addition, the low prevalence of dosimeter use found in this study is probably because most studies included physicians, who are considered less compliant with dosimeter use than other professional groups (except radiologists and cardiologists) [13].

When analyzing the subgroups by continent and comparing Europe with the others, there was a difference of 31 % between Europe and Asia (68 % vs 37 %) and 35 % in the Americas (68 % vs 33 %). However, the number of European studies was lower than in Asia (3 vs 5) and the same as in the Americas. However, the number of individuals was 2.3 times higher in Europe than in Asia and 2.5 times higher in the Americas than in Europe. The African continent subgroup had a 7 % higher global prevalence (75 % vs. 68 %) but had fewer studies (2 vs. 3) and 2.5 times fewer individuals than the European subgroup. The prevalence of studies from Europe ranged from 26 % to 100 %, and the combined prevalence in the subgroup was 68 [95 % IC: 17–100]; 1 study is from 2024 (Portugal) and 2 from 2021 (Germany, Belgium, and the

Netherlands). However, these studies alone were not sufficient to assess the impact of Directive 2013/59/EURATOM.

In Portugal, monitoring with an individual whole-body dosimeter at chest level under personal protective equipment (PPE) (e.g. apron) is mandatory and corresponds to the assessment of $H_p(10)$ and $H_p(0.07)$. The individual extremity dosimeter (ring or bracelet) is for additional use (recommended if doses greater than 3/10 of the legal dose limit are expected in the extremities and placed at the extremity closest to the source) and corresponds to the assessment of $H_p(0.07)$. The lens eyes dosimeter evaluates $H_p(3)$, which is currently the most accurate method, and it is recommended to be placed next to the eye closest to the source [105–107]. Estimating a dose to the lens of the eye with a single dosimeter at chest level may not yield the most accurate results, as an effective dose may be overestimated if the dosimeter is placed above the PPE and underestimated if it is placed below the PPE [16,107]. The ICRP recommends interventional procedures using one dosimeter at chest level under the PPE and a second dosimeter above the PPE at collar level to provide an estimate of the most effective dose to the lens of the eye and head, and to confirm that the PPE was actually worn [16,106,108].

In the studies included, the highest bias was due to the validity and reliability of the instruments applied. The reliability and validity of instruments are two indispensable characteristics essential for generating beneficial, systematic, and reliable results. Although closely related, they express different properties of the instrument [109,110]. Brun et al. [55] mentioned the lack of validated questionnaires for RP. Ranade et al. [84] asserted that such validation was unnecessary, as the questionnaire was intended to assess knowledge and practice. The existing literature references the scarcity of validated and reliable questionnaires for the RP area [102,111]. Applying these tools is crucial for developing programs to address problems and estimate educational and managerial needs. These tools are of significant value in diagnosing needs, benchmarking, and evaluating intervention measures. This allows for improving PR culture [102].

The personal dosimeters can be passive or active (or electronic) [16]. Passive personal dosimeters are small, lightweight, and require no power. These dosimeters record the total accumulated exposure value over a period and are used for legal monitoring. The absence of an instantaneous reading capability represents a disadvantage of passive dosimeters for optimizing monitoring [16,105]. In contrast, the active personal dosimeter that functions in real-time is employed for the employer's internal registration purposes [105]. Some countries are also accepted as official dosimeters, but this practice is still minimal [7]. The dose rate or cumulative dose value is instantaneous and can have preset alarms, providing workers with quick feedback on their exposure. This allows them to make informed decisions during occupational exposure, modify their behavior accordingly, increase awareness of radiation exposure, increase compliance with PR measures, and provide immediate feedback on corrective actions such as shield positioning and distance from the radiation source. As a result, they can be beneficial in reducing occupational doses [7,16,105,112–119]. However, low-energy photons in pulsed radiation fields occur frequently in clinical practice in fluoroscopy-guided procedures, and the response of most of these dosimeters tends to decrease as the instantaneous personal equivalent dose rate increases, probably due to the temporal response of the electronic system [7,120]. Dosimeters must comply with regulatory requirements (e.g. in terms of energy response, angular response, and dose rate range), regular calibrations, and functional tests considering the characteristics of the radiation beam in which the dosimeters are used to provide reliable information [7]. This study revealed that active personal dosimeters were little investigated and had a low average use.

Active personal dosimeters, when connected to dose management systems, enable real-time monitoring of occupational radiation exposure. This allows analysis by procedure and comparison with the ambient dose measured by a reference dosimeter in the C-arm. The ratio of personal to ambient dose equivalents serves as an indicator of the effectiveness of protective measures, such as suspended screens.

Automatic alerts triggered by high personal dose equivalent values or a high personal-to-ambient dose equivalent ratio help to identify inappropriate practices, particularly in simple procedures where protection is often neglected [121]. Wickramasinghe, Sachini et al. [122] emphasize the importance of accurately monitoring radiation doses to the eye lens to avoid exceeding the annual ocular dose limit, as they found in cardiologists. They demonstrate the feasibility of estimating the eye lens dose indirectly using $H_p(10)$ and $H_p(0.07)$ measurements when dedicated dosimeters are unavailable. In their study, a dedicated active $H_p(3)$ eye lens dosimeter and an $H_p(10)$ dosimeter were positioned on the left side of the thyroid collar.

In this study, there was a lack of education/training for individuals, with less than half of the respondents reporting that they had education/training, which aligns with other studies (e.g. [102,122]). Safety education and training are important strategies for improving safety performance, although knowledge alone does not lead to behavioral change [123,124]. Müller et al. [72] evaluated before and after a structured education program and found that no one had used the dosimeter before or after two individuals started using it. Brun et al. [55] evaluated practices and knowledge before and after training. They found a short-term improvement in knowledge after training but no improvement in practices, which may reveal the need to modify training strategies. For training to be effective, appropriate methods must be adopted, and the reality of the organization, the work environment, and the determinants of behavioral change must be identified. Training techniques that require workers' involvement and active participation are considered beneficial in promoting safe behavior [123].

PR culture is considered a set of attitudes, strategies, practices, priorities, and policies among workers and leaders that should be emphasized in effects-oriented PR and risks of ionizing radiation [104]. Doyen, Vlerick et al. [124] found that developing a strong PR climate and training can also improve a team's PR safety knowledge, promoting safe behaviors. In the studies included, there was no 100 % use of full-body dosimeters. Some individuals did not have a dosimeter, reported that readings were not taken regularly, did not have access to reading reports, forgot to put the dosimeter on, and lacked policies enforcing the use of dosimeters, etc. These findings suggest a lack of culture in PR.

Matsuzaki et al. [74] evaluated the implementation of a preoperative briefing before starting radiological procedures. The correct use of dosimeters was checked and confirmed verbally in the briefing. Operators were encouraged to use the dosimeter correctly if they showed any deficiencies. It found a statistically significant increase in dosimeter use and a statistically significant increase in dose exposure, which raised the hypothesis of neglected exposure up to the time of the intervention and changes in the dosimeter management method from a single to dual dosimeter approach.

The strength of this *meta-analysis* is that it is the first study to show the estimated overall prevalence. This study has limitations that should be considered to better evaluate the main conclusions. The research instrument was the questionnaire, the most common instrument in prevalence studies. A systematic review on healthcare workers' knowledge, attitude, and practice toward RP found that the self-report questionnaire was used in 100 % of the studies [125]. For this reason, our research focused on this instrument. Self-reporting was the most common method used. When interpreting the results of these studies, the limitations inherent in this type of instrument should be considered, such as interpretation bias, dishonest response bias, and social desirability bias (i.e., the tendency of participants to respond in a way that is viewed favorably by others). Another limitation of this review is the heterogeneity among studies and the presence of a significant number of studies with a moderate risk of bias and two studies with a high risk of bias, which makes it necessary to be more cautious when analyzing the studies and results. Also, there were only two studies per subgroup in the *meta-analysis*. This may affect the robustness and reliability of subgroup analysis results. The results should be interpreted cautiously due to the limited number of included studies, and search results may be affected

by the search strategy.

For future studies, it is suggested that valid and reliable instruments on dosimeter use and individual and organizational factors be developed to standardize, allow benchmarking, and examine relationships between different variables, as other factors, such as dosimeter location, are also essential for obtaining reliable dose estimation results. A more in-depth study of this variable is suggested because workers may underestimate or overestimate dose values if they do not use dosimeters correctly. Internal audits, pre-procedure briefings, storage of dosimeters in more visible locations to minimize forgetfulness, improvement of institutional policies, and on-the-job and academic training/education are recommended.

5. Conclusion

This study provides an updated estimate of the prevalence of personal monitoring dosimeters and identifies factors contributing to the prevalence. The low prevalence values for dosimeters provided in this study may indicate that exposure doses in workers are being underestimated. Active dosimeters can contribute to behavioral change by optimizing exposure doses. Using valid and reliable scales, further studies are needed to assess the dosimeter use and the individual and organizational factors that may contribute to it. In addition, data

comparability is a challenge internally, nationally, and externally, and it can be carried out with other countries, helping to promote continuous improvement in the safety of exposed workers through accurate monitoring. To emphasize dosimeter use, more actions are needed to change individual and organizational factors.

Therefore, considerable efforts are still required to ensure adequate radiation safety for medical workers exposed to ionizing radiation in fluoroscopy-guided procedures. Raising awareness of this issue is crucial, particularly among those responsible for implementing and overseeing the application of radiation safety regulations and procedures.

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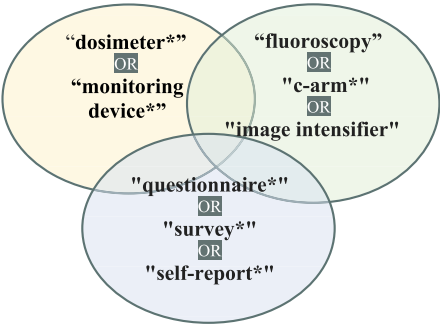
Declaration of competing interest

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.

Appendices

Appendix A

Keywords - the search represents the intersection of the three sets of keywords.



Search strategy				
Keywords/ Mesh	Search terms	Database	Filters	
			01/01/ 2018–13- 04–2024	Others
• Keywords	("dosimeter*" OR "monitoring device*") AND ("fluoroscopy" OR "c-arm*" OR "image intensifier") AND ("questionnaire*" OR "survey*" OR "self-report*")	• PubMed • Academic Search Complete (through EBSCOhost) • Scopus • Web of Science Core Collection • ScienceDirect • PubMed	Yes Yes Yes Yes Yes Yes	No Scientific journals- peer-reviewed Document type No Document type No
• MeSH	("radiation dosimeters"[MeSH Terms]) AND ("Fluoroscopy"[MeSH]) AND ("surveys and questionnaires"[MeSH Terms] OR "self report"[MeSH Terms])			

Appendix B

Search results as of 13 April 2024.

Keywords/ Mesh	Search terms	Database	Results			
			No Filters	With filters 01/01/ 2018–13/4/ 2024	Others	Final
• Keywords	("dosimeter*" OR "monitoring device*") AND ("fluoroscopy" OR "c-arm*" OR "image intensifier") AND ("questionnaire*" OR "survey*" OR "self-report*")	• MEDLINE (through PubMed)	57	26	No	26
		• Scopus	600	268	218 (article)	218
		• Web of Science Core Collection	55	30	No	30
		• Academic Search Complete(through EBSCOhost)	13	7	6(Scientific journals- peer-reviewed)	6
• Mesh	("dosimeter" OR "monitoring device") AND ("fluoroscopy" OR "c-arm" OR "image intensifier") AND ("questionnaire" OR "survey" OR "self-report")	• ScienceDirect	802	249	94 (article)	94
		• MEDLINE(through PubMed)	1	1	No	1
			1528	581	375	375
				947	206 (205 article +1 peer-reviewed)	1153
Results: Records included (n)						
Records deleted (n)						

Appendix C

Snowballing (Traceability)
Full access is available at: https://docs.google.com/spreadsheets/d/1O-qRUvFNOuR5gaAAeUnlYqOFFlyXy-MY/edit?usp=drive_link&ouid=114964709382943245472&rtpof=true&sd=true.

Snowballing (Traceability) - 14/05/2024 - 17/05/2024													
Studies included				Backward (References)									
Study	Author(s)	Source	Total	Post 201	Eligibl	Author(s)	Source	Study originat	Include	Exclude	Duplicat	Reason	No acce
A1	Costa et al., 2024	https://www.scopus.com/record/	23	7	1	Uthirapathy et al., 2022	https://www.scopus.com/record/		0	1	1	Database included	
A2	Fontanet Soler et al., 2024	https://www.scopus.com/record/	35	14	3	Hayashi et al., 2021	https://www.scopus.com/record/		0	3	1	Database included	
A3	Gayán-Fernández et al., 2023	https://www.scopus.com/record/	28	3	1	Chng et al., 2021	https://doi.org/10.1101/2021.03.01.20210101		0	1	1	Database included	
A4	Hayashi et al., 2023	https://www.scopus.com/record/	21	10	3	Fidan et al., 2019	https://pubmed.ncbi.nlm.nih.gov/34010101/		0	3	1	Database included	
A5	Hijkata et al., 2023	https://www.scopus.com/record/	21	11	3	Serhi et al., 2019	https://doi.org/10.1101/2019.03.01.20210101		0	3	1	Database included	
B1	Kang et al., 2020	https://www.scopus.com/record/	31	5	2	Falavigna et al., 2018	https://www.scopus.com/record/		0	3	1	Database included	
B2	Joeris et al., 2018	https://www.researchgate.net/publication/32110101	30	0	0	Fidan et al., 2019	https://pubmed.ncbi.nlm.nih.gov/34010101/		0	3	1	Database included	
B3	Alshabi et al., 2022	https://www.ccsenet.org/article/view/10101	15	4	3	Kang et al., 2020	https://www.researchgate.net/publication/32110101		0	3	1	Database included	
B4	Bukhari et al., 2021	https://journalms.com/assessme	13	1	1	Papendrop et al., 2020	https://pubmed.ncbi.nlm.nih.gov/34010101/		0	3	1	Database included	
B5	Mulati et al., 2024	https://www.researchsquare.com/publication/32110101	28	10	5	Bukhari et al., 2021	https://journalms.com/assessme		0	3	1	Database included	
B6	Almali et al., 2021	https://www.scopus.com/record/	36	6	1	Omar et al., 2021	https://www.researchgate.net/publication/32110101		0	3	1	Database included	
A6	Kumar et al., 2024	https://www.scopus.com/record/	26	10	6	Bukhari et al., 2021	https://journalms.com/assessme		0	3	1	Database included	
A7	Patel et al., 2023	https://www.scopus.com/record/	23	11	0	AlMohammad et al., 2022	https://pubmed.ncbi.nlm.nih.gov/34010101/		0	3	1	Database included	
A8	Mohammad et al., 2022	https://www.scopus.com/record/	30	12	9	Pires et al., 2020	https://pubmed.ncbi.nlm.nih.gov/34010101/		0	3	1	Database included	

Forward (Citations)											
Total	Eligible	Author(s)	Source	Study originat	Include	Exclude	Duplicat	Reason	No acce	Contex	Language
1	0				0	0					
0	0				0	0					
1	0				0	0					
1	0				0	0					
4	0				0	0					
9	5	Lee et al., 2022 Hijkata et al., 2023 Al Mohammad et al., 2022 Alshabi et al., 2022 Cho et al., 2024	https://pubmed.ncbi.nlm.nih.gov/ https://www.mdpi.com/ https://pubmed.ncbi.nlm.nih.gov/ https://www.cureus.com/ http://dx.doi.org/10.512		1	4	1	Database included Database included Database included			1
10	4	Kang et al., 2020 Al Mohammad et al., 2022 Lee et al., 2022 Sheth et al., 2022	https://www.scopus.co https://pubmed.ncbi.nlm.nih.gov/ https://pubmed.ncbi.nlm.nih.gov/ https://www.sciencedi		0	4	1	A5 → B1 included Database included Database included Database included			
2	1	Cho et al., 2024	http://dx.doi.org/10.512		0	1					1
5	3	Alshabi et al., 2022 Mulat et al., 2024 Almaki et al., 2021	https://www.cureus.com/ https://doi.org/10.21203 https://journalsr.com/	B5 B6	2	1	1	A5 → B3 included			
0	0				0	0					
0	0				0	0					
0	0				0	0					
0	0				0	0					
1	1	Kumar et al., 2024	https://link.springer.co		0	1	1	Database included			

Appendix D. Studies included databases

Coding	Reference	Publication (year)	References (n)	Citations (n)
A1	Costa, H., Vinhas, H., Calé, R., Pereira, E., Santos, J., Paulo, G., Jorge, E., Brochado, B., Melica, B., Baptista Gonçalves, R., & Infante de Oliveira, E. (2024). A report on a survey among Portuguese Association of Interventional Cardiology associates regarding ionizing radiation protection practices in national interventional cath-labs. <i>Revista Portuguesa de Cardiologia</i> , 43(4), 177–185. https://doi.org/10.1016/j.repc.2023.07.008	2024	23	1
A2	Fontanet Soler, S., Bravo-Balado, A., Skolarikos, A., Seitz, C., Traxer, O., Talso, M., Ventimiglia, E., Villa, L., Pietropaolo, A., Keller, E. X., Kallidonis, P., Sener, T. E., Nagele, U., De Coninck, V., Hameed, Z., Tsaturyan, A., Juliebo-Jones, P., Mikoniat, I., Wiseman, O., ... Emiliani, E. (2024). Trends in the use of radiation protection and radiation exposure of European endourologists: a prospective trial from the EULIS-YAU Endourology Group. <i>World Journal of Urology</i> , 42(1). https://doi.org/10.1007/s00345-024-04854-0	2024	35	0
A3	Gaytán-Fernández, S., Barragan-Hervella, R. G., Quiroz-Williams, J., Rodríguez Palacios, C. L., & Sánchez-González, G. (2023). Exposure to ionizing radiation in orthopedic residents in a referral hospital. <i>Cirugia y Cirujanos (English Edition)</i> , 91(1), 64–72. https://doi.org/10.24875/CIRU.21000644	2023	28	1
A4	Hayashi, S., Takenaka, M., Kogure, H., Yakushijin, T., Nakai, Y., Ikezawa, K., Yamaguchi, S., Fujisawa, T., Tamaru, Y., Maetani, I., Maruyama, H., Asai, S., Takagi, T., Nagaike, K., Hori, Y., Sumiyoshi, T., Tsumura, H., Doyama, H., Yoshio, T., ... Nishida, T. (2023). A follow-up questionnaire survey 2022 on radiation protection among 464 medical staff from 34 endoscopy–fluoroscopy departments in Japan. <i>DEN Open</i> , 3(1). https://doi.org/10.1002/deo2.227	2023	21	1
A5	Hijkata, Y., Kotani, Y., Suzuki, A., Morota, K., Funao, H., Miyagi, M., Morimoto, T., Kanno, H., & Ishii, K. (2023). Protective Attitudes toward Occupational Radiation Exposure among Spine Surgeons in Japan: An Epidemiological Description from the Survey by the Society for Minimally Invasive Spinal Treatment. <i>Medicina (Lithuania)</i> , 59(3). https://doi.org/10.3390/medicina59030545	2023	21	4
A6	Kumar, S., Sinha, S., Khan, Y., Kumar, A., Qureshi, O. A., & Jameel, J. (2024). Knowledge, Attitude, and Practices Regarding Radiation and its Hazards Among Orthopaedic Surgeons in India: A Questionnaire-Based Study. <i>Indian Journal of Orthopaedics</i> , 58(2), 182–189. https://doi.org/10.1007/s43465-023-01068-1	2024	26	0
A7	Patel, S., Jenkins, P., Zhong, J., Liu, W., Harborne, K., Modi, S., Joy, C., Williams, R., & Haslam, P. (2023). Better safe than so ray: national survey of radiation protection amongst interventional radiology trainees in the United Kingdom. <i>British Journal of Radiology</i> , 96(1149). https://doi.org/10.1259/bjr.20230071	2023	23	0

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Coding	Reference	Publication (year)	References (n)	Citations (n)
A8	Mohammad, B., Gharaibeh, M., & Al Alakhras, M. (2022). Knowledge and practice of radiation protection in the operating theater among orthopedic surgeons. <i>Journal of Medical Imaging</i> , 9(06). https://doi.org/10.1117/1.jmi.9.6.066002	2022	30	1
A9	Lee, W. J., Jang, E. J., Kim, K. S., & Bang, Y. J. (2022). Underestimation of Radiation Doses by Compliance of Wearing Dosimeters among Fluoroscopically-Guided Interventional Medical Workers in Korea. <i>International Journal of Environmental Research and Public Health</i> , 19(14). https://doi.org/10.3390/ijerph19148393	2022	32	0
A10	Matsuzaki, S., Moritake, T., Sun, L., Morota, K., Nagamoto, K., Nakagami, K., Kuriyama, T., Hitomi, G., Kajiki, S., & Kunugita, N. (2022). The Effect of Pre-Operative Verbal Confirmation for Interventional Radiology Physicians on Their Use of Personal Dosimeters and Personal Protective Equipment. <i>International Journal of Environmental Research and Public Health</i> , 19(24). https://doi.org/10.3390/ijerph192416825	2022	36	2
A11	Senel, S., Sandikci, F., Ozerkan, A. Y., Gurtan, E., Sonmez, S. Z., & Demirel, H. C. (2022). Analysis of the Knowledge and Attitude of Turkish Urology Residents on the Use of Fluoroscopy Working in University Hospitals and Training and Research Hospitals: A National Survey-Based Comparative Study. <i>Haseki Tip Bulteni</i> , 60(2), 120–126. https://doi.org/10.4274/haseki.galenos.2022.7969	2022	14	0
A12	Sheth, B., Jesia, A., Parihar, R., Somani, R., & Pawar, P. (2022). Are Indian orthopaedic surgeons aware of the health hazards of radiation exposure? A survey and review on awareness and ways to mitigate them. <i>Journal of Clinical Orthopaedics and Trauma</i> , 32. https://doi.org/10.1016/j.jcot.2022.101982	2022	37	3
A13	Uthirapathy, I., Dorairaj, P., Ravi, S., & Somasundaram, S. (2022). Knowledge and practice of radiation safety in the Catherization laboratory among Interventional Cardiologists – An online survey. <i>Indian Heart Journal</i> , 74(5), 420–423. https://doi.org/10.1016/j.ihj.2022.08.001	2022	9	9
A14	Abdelrahman, M. A., Abu Alfwarees, A., Alewaidat, H., Alhasan, M., Rawashdeh, M. A., & Al Mousa, D. S. (2018). Compliance with Radiation Protection Practices among Radiologists. <i>Health Physics</i> , 115(3), 338–343. https://doi.org/10.1097/HP.0000000000000886	2018	32	6
A15	Altintas, E., Bahceci, T., Batur, A. F., Kaynar, M., Kilic, O., Akand, M., Goktas, S., & Gul, M. (2021). A survey analysis of knowledge levels of urologists about radiation safety and fluoroscopy use. <i>International Journal of Clinical Practice</i> , 75 (4). https://doi.org/10.1111/ijcp.13862	2021	34	8
A16	Asari, T., Rokunohe, D., Sasaki, E., Kaneko, T., Kumagai, G., Wada, K., Tanaka, S., Sawamura, D., & Ishibashi, Y. (2022). Occupational ionizing radiation-induced skin injury among orthopedic surgeons: A clinical survey. <i>Journal of Orthopaedic Science</i> , 27(1), 266–271. https://doi.org/10.1016/j.jos.2020.11.008	2022	16	7
A17	Behr-Meenen, C., von Boetticher, H., Kersten, J. F., & Nienhaus, A. (2021). Radiation protection in interventional radiology/cardiology—is state-of-the-art equipment used? <i>International Journal of Environmental Research and Public Health</i> , 18(24). https://doi.org/10.3390/ijerph182413131	2021	26	7
A18	Brandon, L., & Keane, D. (2021). An assessment of radiation use, knowledge and concerns in trainee cardiologists in Ireland. <i>The British Journal of Radiology</i> , 94(1124), 20201348. https://doi.org/10.1259/bjr.20201348	2021	9	0
A19	Erkan, I., Yarenoglu, A., Yukselolu, E. H., & Ulutin, H. C. (2019). The investigation of radiation safety awareness among healthcare workers in an education and research hospital. <i>International Journal of Radiation Research</i> , 17(3), 447–453. https://doi.org/10.18869/acadpub.ijrr.17.3.447	2019	30	7
A20	Palavigna, A., Ramos, M. B., Iutaka, A. S., Menezes, C. M., Emmerich, J., Taboada, N., & Riew, K. D. (2018). Knowledge and Attitude Regarding Radiation Exposure Among Spine Surgeons in Latin America. <i>World Neurosurgery</i> , 112, e823–e829. https://doi.org/10.1016/j.wneu.2018.01.166	2018	22	14
A21	Fidan, F., Çetin, M. Ü., Kazdal, C., Kiliç, F., & Özkaya, U. (2019). Behaviour and knowledge skill levels of orthopedic surgeons about radiation safety and fluoroscopy use: A survey analysis. <i>Acta Orthopaedica et Traumatologica Turcica</i> , 53(4), 301–305. https://doi.org/10.1016/j.aott.2019.04.008	2019	12	14
A22	Girgin, R. (2021). An Anatolian study on the current knowledge and attitudes of urology operating room staff on ionizing radiation. <i>African Journal of Urology</i> , 27(1). https://doi.org/10.1186/s12301-020-00117-7	2021	19	4
A23	Harris, A. M., Loomis, J., Hopkins, M., & Bylund, J. (2019). Assessment of Radiation Safety Knowledge among Urology Residents in the United States. <i>Journal of Endourology</i> , 33(6), 492–497. https://doi.org/10.1089/end.2019.0133	2019	29	14
A24	Hayashi, S., Takenaka, M., Kogure, H., Yakushijin, T., Maruyama, H., Hori, Y., Yoshio, T., Ikezawa, K., Takagi, T., Asai, S., Matsunaga, K., Matsumoto, K., Tsumura, H., Yamaguchi, S., Sumiyoshi, T., Nagaike, K., Tamaru, Y., Hara, K., Fujisawa, T., ... Nishida, T. (2021). A questionnaire survey on radiation protection among 282 medical staff from 26 endoscopy-fluoroscopy departments in Japan. <i>DEN Open</i> , 1(1). https://doi.org/10.1002/deo2.5	2021	22	7
A25	Henderickx, M. M. E. L., Baard, J., Beerlage, H. P., & Kamphuis, G. M. (2021). Fluoroscopy-use during ureterorenoscopy: are urologists concerned about radiation exposure? A nationwide survey in Belgium and The Netherlands. <i>Acta Chirurgica Belgica</i> , 121(3), 170–177. https://doi.org/10.1080/00015458.2019.1693150	2021	23	3
A26	Patel, A. A., Patel, A. A., & Kaplan, T. D. (2018). Radiation Exposure Safety Patterns with the Use of Intraoperative Fluoroscopy. <i>Bulletin of the Hospital for Joint Disease</i> , 76(3), 183–191.	2018	41	2
A27	Menon, R., Karatasakis, A., Patel, S., Danek, B. A., Karacsonyi, J., Rangan, B. V., Addo, T., Kumbhani, D., Kapadia, S., Luna, M., Mahmud, E., Chambers, C., Banerjee, S., & Brilakis, E. S. (2018). Radiation Safety in the Catheterization Laboratory: Current Perspectives and Practices. <i>The Journal of Invasive Cardiology</i> , 30(8), 296–300.	2018	34	8
A28	Pires, R. E., Reis, I. G. N., De Faria, A. R. V., Giordano, V., Labronici, P. J., & Belangero, W. D. (2020). The hidden risk of ionizing radiation in the operating room: A survey among 258 orthopaedic surgeons in Brazil. <i>Patient Safety in Surgery</i> , 14(1). https://doi.org/10.1186/s13037-020-00238-6	2020	26	12
A29	Pérez-Fentes, D., Pombar-Cameán, M., & Álvarez-Ossorio Fernández, J. L. (2019). Current status of radiological protection in endourological procedures in Spain Estado actual de la protección radiológica en procedimientos endourológicos en España. In <i>Actas Urol Esp</i> (Vol. 43, Issue 4). https://www.elsevier.es/actasuro	2019	24	1
A30	Ranade, A. S., Oka, G. A., Daxini, A., Ardawatia, G., Majumder, D., & Bhaskaran, S. (2020). Radiation Safety Knowledge and Practices: Is the Indian Orthopaedic Community Well-informed? <i>Indian Journal of Orthopaedics</i> , 54, 158–164. https://doi.org/10.1007/s43465-020-00212-5	2020	19	6
A31	Rose, A., Uebel, K., & Duncombe Rae, W. I. (2021). Personal dosimeter utilisation among South African interventionalists. <i>Journal of Radiological Protection</i> , 41(2), 326–336. https://doi.org/10.1088/1361-6498/abf950	2021	24	1
A32	Sethi, S., Barakat, M. T., Friedland, S., & Banerjee, S. (2019). Radiation Training, Radiation Protection, and Fluoroscopy Utilization Practices Among US Therapeutic Endoscopists. <i>Digestive Diseases and Sciences</i> , 64(9), 2455–2466. https://doi.org/10.1007/s10620-019-05564-z	2019	39	19
A33	Thambura, M. J., & Ikiara, N. J. (2020). Anesthesiologist Knowledge on Radiation Safety in Northern Gauteng Hospitals, South Africa. <i>Journal of Radiology Nursing</i> , 39(3), 245–248. https://doi.org/10.1016/j.jradnu.2020.01.004	2020	23	0

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Coding	Reference	Publication (year)	References (n)	Citations (n)
A34	Papendorp, L. W. A., Suleman, F. E., & Hanekom, H. (2020). The knowledge, awareness and practices of radiation safety amongst orthopaedic surgeons. <i>South African Journal of Radiology</i> , 24(1). https://doi.org/10.4102/sajr.v24i1.1806	2020	12	8
A35	Wan, R. C. W., Chau, W. W., Tso, C. Y., Tang, N., Chow, S. K. H., Cheung, W. H., & Wong, R. M. Y. (2021). Occupational hazard of fluoroscopy: An invisible threat to orthopaedic surgeons. <i>Journal of Orthopaedics, Trauma and Rehabilitation</i> , 28. https://doi.org/10.1177/22104917211035547	2021	65	6
A36	Whitney, G. M., Thomas, J. J., Austin, T. M., Fanfan, J., & Yaster, M. (2019). Radiation Safety Perceptions and Practices among Pediatric Anesthesiologists: A Survey of the Physician Membership of the Society for Pediatric Anesthesia. <i>Anesthesia and Analgesia</i> , 128(6), 1242–1248. https://doi.org/10.1213/ANE.0000000000003773	2019	23	8
Total			939	184

Notes: A1-A36 – coding the sources databases;

Appendix E. Studies excluded from databases

Coding	Reference	Reason for exclusion
A37	Alasmari, Y., Alnowami, M. R., Alkhateeb, S. M., & Djouider, F. (2023). Assessment of radiographers' understanding of radiation safety and their occupational radiation exposure in the Asir region of Saudi Arabia. <i>Radiation Physics and Chemistry</i> , 212, 111148. https://doi.org/10.1016/j.radphyschem.2023.111148	Context
A38	Alshumrani, G. (2021). Radiation protection practice of medical doctors of surgical and interventional specialties in Saudi Arabia. <i>Radioprotection</i> , 56(1), 49–53. https://doi.org/10.1051/radiopro/2020069	Context
A39	Bhinder, J., Fakhoury, E., O'Brien-Irr, M., Reilly, B., Dryjski, M., Dosluoglu, H., Cherr, G., & Harris, L. (2022). National survey of vascular surgery residents and fellows on radiation exposure and safety practices. <i>Journal of Vascular Surgery</i> , 76(1), 274–279.e1. https://doi.org/10.1016/j.jvs.2021.12.080	Conference paper
A40	D'Avino, V., Angrisani, L., La Verde, G., Pugliese, M., Raulo, A., Sabatino, G., & Coppola, F. (2019). New Eye Lens Dose Limit: Status of Knowledge in Campania Hospitals. <i>International Journal of Environmental Research and Public Health</i> , 16(18), 3450. https://doi.org/10.3390/ijerph16183450	Context
A41	Fiagbedzi, E., Gorleku, P. N., Nyarko, S., Asare, A., & Ackah Ndele, G. (2022). Assessment of radiation protection knowledge and practices among radiographers in the central region of Ghana. <i>Radiation Medicine and Protection</i> , 3(3), 146–151. https://doi.org/10.1016/j.radmp.2022.06.001	Context
A42	Harris, A., Loomis, J., Hopkins, M., & Bylund, J. (2019). Assessment of Radiation Safety Knowledge among House Staff Exposed to Fluoroscopic Radiation. <i>Urology Practice</i> , 6(2), 140–145. https://doi.org/10.1016/j.urpr.2018.05.002	No access
A43	Jia, R., Chen, B., Gao, Z., Bei, W., & Chen, C. (2019). Analysis on occupational radiation protection status and influencing factors in a tertiary hospital in Shanghai. <i>Chinese Journal of Radiological Health</i> , 28(6), 637–641. https://doi.org/10.13491/j.issn.1004-714x.2019.06.011	Language
A44	Khan, J., Khalid, B., Abbasi, M. Z., Ashraf, R. A., Asghar, K., Nadeem Kashmiri, M., Tousif, K., Shahzad, F., Basit, J., Haider, T., Shabbir, H., Rauf Khalid, A., & Saeed, S. (2023). Enhancing Radiation Safety Culture: Investigating the Mediating Role of Awareness Among Orthopedic Doctors and Operation Theatre Assistants. <i>Cureus</i> . https://doi.org/10.7759/cureus.41704	Condition
A45	Kurtul, S., & Kurtul, N. (2018). The level of knowledge about radiation safety and the frequency of the use of protective equipment among healthcare workers exposed to radiation in different units. <i>Turk Onkoloji Dergisi</i> , 33(3), 102–107. https://doi.org/10.5505/tjo.2018.1795	Context
A46	Maina, P. M., Motto, J. A., & Hazell, L. J. (2020). Investigation of radiation protection and safety measures in Rwandan public hospitals: Readiness for the implementation of the new regulations. <i>Journal of Medical Imaging and Radiation Sciences</i> , 51(4), 629–638. https://doi.org/10.1016/j.jmir.2020.07.056	Condition
A47	Mohd Ridzwan, S. F., Bhoo-Pathy, N., Wee, L. H., & Isahak, M. (2021). Beliefs, Facilitating Factors, and Barriers in Using Personal Dosimeter among Medical Radiation Workers in a Middle-Income Asian Setting. <i>Annals of Work Exposures and Health</i> , 65(8), 940–954. https://doi.org/10.1093/annweh/wxab025	Context
A48	Qureshi, F., Ramprasad, A., & Derylo, B. (2022). Radiation Monitoring Using Personal Dosimeter Devices in Terms of Long-Term Compliance and Creating a Culture of Safety. <i>Cureus</i> , 14(8), e27999. https://doi.org/10.7759/cureus.27999	Context
A49	Salim, F., Nowshin, I., & Begum, M. (2022). Awareness and use of PPE among radiographic workers working in some selected Government and Private Hospital in Dhaka City. <i>Bangladesh Journal of Medical Science</i> , 21(1), 114–119. https://doi.org/10.3329/BJMS.V21i1.56336	Context
A50	Cho, S., Lee, H., Kang, M., Lee, W. J., & Ko, S. (2024). Current status of occupational radiation exposure and protection among medical interns and residents. <i>Journal of the Korean Medical Association</i> , 67(2), 134–146. https://doi.org/10.5124/jkma.2024.67.2.134	Language
A51	Sierra, L. A. M., Katsnelson, J. Y., & Pineda, D. M. (2022). Occupational Radiation Exposure Among General Surgery Residents: Should We Be Concerned? <i>Journal of Surgical Education</i> , 79(2), 463–468. https://doi.org/10.1016/j.jsurg.2021.10.016	Condition
A52	Yashima, S., & Chida, K. (2022). Awareness of Medical Radiologic Technologists of Ionizing Radiation and Radiation Protection. <i>International Journal of Environmental Research and Public Health</i> , 20(1), 497. https://doi.org/10.3390/ijerph20010497	Condition
A53	Zekioglu, A., & Parlar, S. (2021). Investigation of awareness level concerning radiation safety among healthcare professionals who work in a radiation environment. <i>Journal of Radiation Research and Applied Sciences</i> , 14(1), 1–8. https://doi.org/10.1080/16878507.2020.1777657	Context

Notes:– coding the sources databases

Appendix F. Studies included from snowballing

Coding	Reference	Publication (year)	References (n)	Citations (n)
B1	Kang, S., Cha, E. S., Bang, Y. J., Na, T. W., Lee, D., Song, S. Y., & Lee, W. J. (2020). Radiation exposure and fluoroscopically-guided interventional procedures among orthopedic surgeons in South Korea. <i>Journal of Occupational Medicine and Toxicology</i> , 15(1). https://doi.org/10.1186/s12995-020-00276-x	2020	31	9
B2	Joeris, A., Goldhahn, S., Kalampoki, V., & Gebhard, F. (2018). Intraoperative Radiation Exposure of Orthopaedic Surgeons-Mismatch Between Concerns and Protection. <i>Occupational Medicine & Health Affairs</i> , 06(02). https://doi.org/10.4172/2329-6879.1000273	2018	30	10

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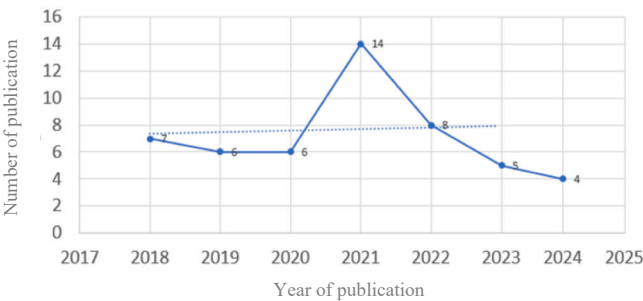
(continued)

Coding	Reference	Publication (year)	References (n)	Citations (n)
B3	Alshabi, Y. A., Yasawy, M. A., Makhdoom, A. K., Kablaghli, R. A., Alanazi, K. S., Eid, S. M., & Imran, W. M. (2022). Knowledge Regarding Ionizing Radiation Exposure Safety Among Orthopedic Surgeons at Hospitals in Al-Madinah. <i>Cureus</i> . https://doi.org/10.7759/cureus.30738	2022	15	2
B4	Bukhary, H. A., Aldosari, A. M., & Althagafi, A. S. (2021). Assessment of Knowledge and Awareness Regarding Radiation Safety and Fluoroscopy Use among Orthopedic Surgeons in Saudi Arabia. <i>Journal of Musculoskeletal Surgery and Research</i> , 5(1), 35–40. https://doi.org/10.4103/jmsr.jmsr_100_20	2021	13	5
B5	Mulat, K. A., Tsehaye, M., Akalu, G. T., Kebede, M. A., & Abate, K. (2024). Knowledge, Attitude and Practice of Radiation Safety Precautions among Orthopedic Residents and Consultants in Addis Ababa Burn, Emergency and Trauma Hospital and Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia. <i>Research Square</i> . https://doi.org/10.21203/rs.3.rs-3813347/v1	2024	28	0
B6	Almalki, A. H., Almalki, M. A., Alballa, R. S., Alshaygy, I. S., & Alrabai, H. M. (2021). The compliance with radiation protection and knowledgabout radiation exposure among the orthopedic operating room personnel in Saudi Arabia. <i>Journal of Musculoskeletal Surgery and Research</i> , 5(3), 178–186. https://doi.org/10.25259/JMSR_48_2021	2021	36	0
B7	Raza, M., Geleit, R., Houston, J., Williams, R., & Trompeter, A. (2021). Radiation in orthopaedics (RIO) study: a national survey of UK orthopaedic surgeons. <i>The British Journal of Radiology</i> , 94(1125). https://doi.org/10.1259/bjr.20210736	2021	31	6
B8	Kumar, V., Kumar Pal, A., Ks, S., Manikandan, R., Dorairajan, L. N., Kalra, S., Kandasamy, S., & Khan, M. (2021). Effect of Structured Educational Program on Practices of Radiation Safety Measures Among Health Care Providers in Urology Operation Theater. <i>Cureus</i> . https://doi.org/10.7759/cureus.15765	2021	21	2
B9	Tefera, E., Qureshi, S. A., Gezmu, A. M., & Mazhani, L. (2020). Radiation protection knowledge and practices in interventional cardiologists practicing in Africa: A cross sectional survey. <i>Journal of Radiological Protection</i> , 40(1), 311–318. https://doi.org/10.1088/1361-6498/ab5840	2020	36	3
B10	Brun, A., Mor, R. A., Bourrelly, M., Dalivoust, G., Gazazian, G., Boufercha, R., Lehucher-Michel, M. P., & Sari-Minodier, I. (2018). Radiation protection for surgeons and anesthetists: Practices and knowledge before and after training. <i>Journal of Radiological Protection</i> , 38(1), 175–188. https://doi.org/10.1088/1361-6498/aa9dbd	2018	32	18
B11	Nagamoto, K., & Kunugita, N. (2023). Effectiveness of a radiation management safety checklist for non-vascular imaging and interventional radiology at a medical facility. <i>Environmental and Occupational Health Practice</i> , 5(1). https://doi.org/10.1539/eohp.2022-0016-OA	2023	31	0
B12	Ong, K., Warren, H., Nalagatla, S., Kmiotek, E., Obasi, C., Shanmugathas, N., Beech, H., Chan, L., Colemeadow, J., Ibrahim, I., Waqar, M., Lane, J., Rehman, O. F., & Mankanjuola, J. (2021). Radiation Safety Knowledge and Practice in Urology Theaters: A Collaborative Multicenter Survey. <i>Journal of Endourology</i> , 35(7), 1084–1089. https://doi.org/10.1089/end.2020.0955	2021	23	7
B13	Barbosa, H. B., & Silva, A. M. M. da. (2022). Perception o Orthopedics Surgeons about the Risks of Radiation Exposure in Fluoroscopy. <i>Revista Brasileira de Ortopedia</i> , 57(4), 546–551. https://doi.org/10.1055/s-0042-1748968	2021	30	0
B14	Domienik-Andrzejewska, J., Ciraj-Bjelac, O., Askounis, P., Covens, P., Dragusin, O., Jacob, S., Farah, J., Gianicolo, E., Padovani, R., Teles, P., Widmark, A., & Struelens, L. (2018). Past and present work practices of European interventional cardiologists in the context of radiation protection of the eye lens—results of the EURALOC study. <i>Journal of Radiological Protection</i> , 38(3), 934–950. https://doi.org/10.1088/1361-6498/aac64b	2018	22	20
Total			379	82

Notes: B1-B14 – coding the sources snowballing.

Appendix G

Distribution of publications by year.



Appendix H. Analysis of publications

Journal	Author(s)	Studies (n)	SJR*/JIF# Quartile (n)	Database (%)	Snowballing (%)	Total (%)
Acta Chirurgica Belgica	[68]	1	Q3/Q4	2		2
Acta Orthopaedica et Traumatologica Turcica	[61]	1	Q2/Q4	2		2
Actas Urologicas Espanolas	[82]	1	Q3/Q4	2		2
African Journal of Urology	[64]	1	Q3/ND	2		2
Anesthesia and Analgesia	[93]	1	Q1/Q1	2		2
Bulletin of the Hospital for Joint Diseases	[80]	1	ND/ND	2		2
Cureus Journal of Medical Science	[49,96]	2	ND/ND		4	4

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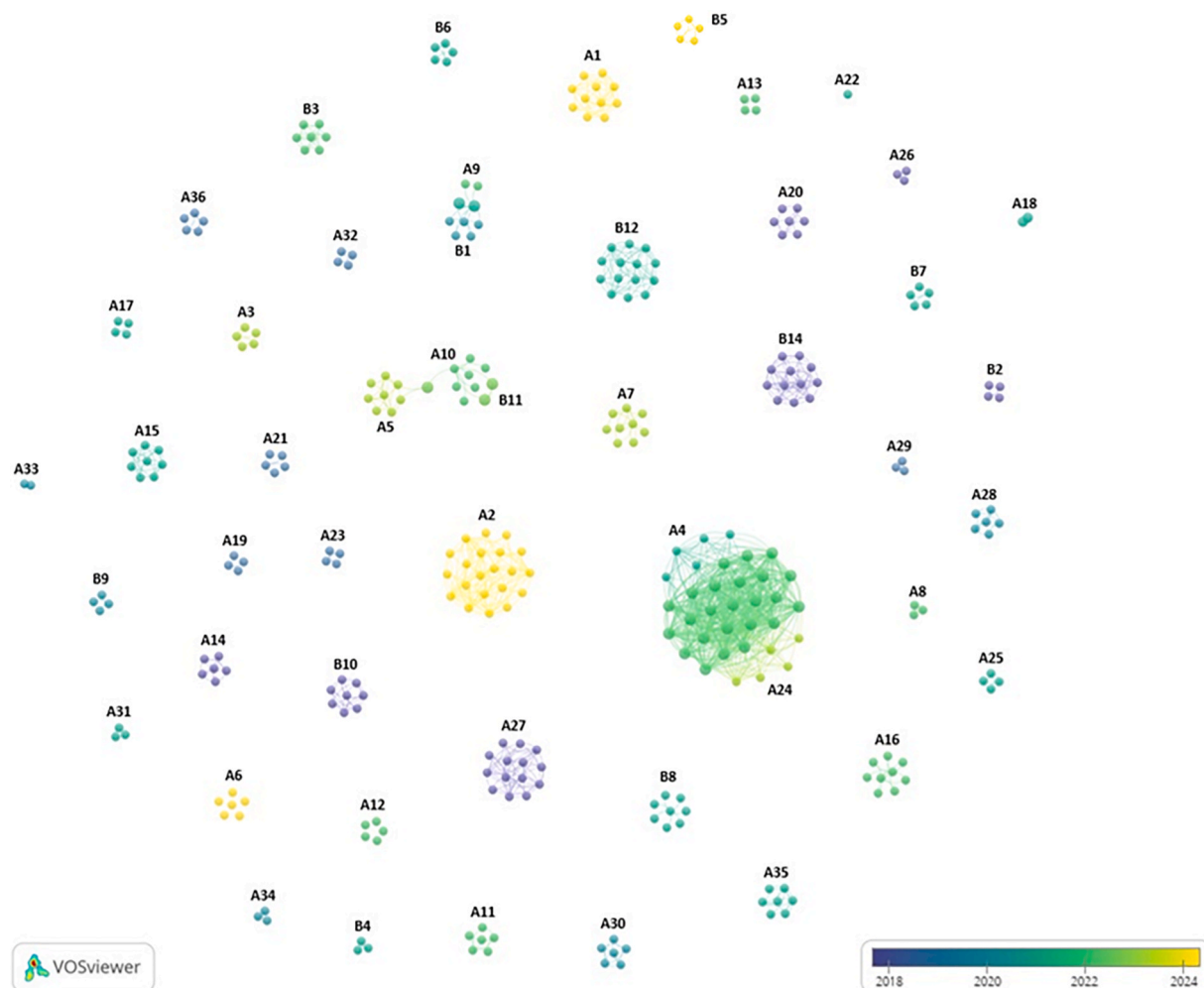
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Journal	Author(s)	Studies (n)	SJR*/JIF# Quartile (n)	Database (%)	Snowballing (%)	Total (%)
DEN Open	[66,67]	2	ND/ND	4		4
Digestive Diseases and Sciences	[95]	1	Q1/Q3	2		2
Haseki Tıp Bulteni-Medical Bulletin of Haseki	[87]	1	ND/ND	2		2
Health Physics	[47]	1	Q2/ND	2		2
Indian Heart Journal	[91]	1	Q3/ND	2		2
Indian Journal of Orthopaedics	[73,84]	2	Q3/Q4	4		4
International Journal of Clinical Practice	[50]	1	Q2/Q3	2		2
International Journal of Environmental Research and Public Health	[13,53,74]	3	Q2/ND	6		6
International Journal of Radiation Research	[59]	1	Q4/Q4	2		2
Journal of Clinical Orthopaedics and Trauma	[88]	1	Q2/ND	2		2
Journal of Endourology	[65,78]	2	Q1/Q2	2	2	4
Journal of Medical Imaging	[75]	1	Q2/ND	2		2
Journal of Musculoskeletal Surgery and Research	[48,56]	2	Q4/ND		4	4
Journal of Occupational Medicine and Toxicology	[98]	1	Q1/Q3		2	2
Journal of Orthopaedics, Trauma and Rehabilitation	[92]	1	Q4/ND	2		2
Journal of Radiological Protection	[55,58,86,89]	4	Q3/Q3	2	6	8
Medicina (Lithuania)	[126]	1	Q2/Q3	2		2
Occupational Medicine & Health Affairs	[70]	1	ND/ND		2	2
Patient Safety in Surgery	[83]	1	Q2/ND	2		2
Research Square	[76]	1	ND/ND		2	2
Revista Brasileira de Ortopedia	[52]	1	Q3/ND		2	2
Revista Portuguesa de Cardiologia	[127]	1	Q3/Q4	2		2
South African Journal of Radiology	[79]	1	Q4/ND	2		2
British Journal of Radiology	[54,81,85]	3	Q1/Q3	4	2	6
Journal of Invasive Cardiology	[94]	1	Q2/Q4	2		2
World Journal of Urology	[62]	1	Q1/Q2	2		2
Journal of Orthopaedic Science	[51]	1	Q2/Q3	2		2
Journal of Radiology Nursing	[90]	1	Q3/ND	2		2
Environmental and Occupational Health Practice	[77]	1	ND/ND		2	2
Cirugia y Cirujanos	[63]	1	Q3/Q4	2		2
World Neurosurgery	[60]	1	Q2/Q3	2		2
Total (%)						
[Q1-Q2] – SJR*/JIF# Quartile			17*/3#	38*/6#	6*/2#	44*/8#
[Q3-Q4] – SJR*/JIF# Quartile			14*/16#	26*/34#	12*/10#	38*/44#
ND – SJR*/JIF# Quartile			7*/19#	8*/32#	10*/16#	18/48#

*SJR – SCImago Journal Rank seen on <https://www.scimagojr.com/>; #JIF – Journal Impact Fact seen on <https://jcr.clarivate.com/> in 16/06/2024; ND = not discriminated.

Appendix I

Author collaboration in included studies with scale time (VOSviewer).



Note: visualized as larger balls – 2 publications included in this review; A1 – Costa et al. (2024); A2 – Fontanet Soler et al. (2024); A3 – Gaytán-Fernández et al. (2023); A4 – Hayashi et al. (2023); A5 – Hijikata et al. (2023); A6 – S. Kumar et al. (2024); A7 – Patel et al. (2023); A8 – Mohammad et al. (2022); A9 – Lee et al. (2022); A10 – Matsuzaki et al. (2022); A11 – Senel et al. (2022); A12 – Sheth et al. (2022); A13 – Uthirapatia et al. (2022); A14 – Abdelrahman et al. (2018); A15 – Altintas et al. (2021); A16 – Asari et al. (2022); A17 – Behr-Meenen et al. (2021); A18 – Brandon et al. (2021); A19 – Erkan et al. (2019); A20 – Falavigna et al. (2018); A21 – Fidan et al. (2019); A22 – Girgin et al. (2021); A23 – Harris et al. (2019); A24 – Hayashi et al. (2021); A25 – Henderickx et al. (2021); A26 – Patel et al. (2018); A27 – Menon et al. (2018); A28 – Pires et al. (2020); A29 – Pérez-Fentes et al. (2019); A30 – Ranade et al. (2020); A31 – Rose et al. (2021); A32 – Sethi et al. (2019); A33 – Thambura & Ikiara (2020); A34 – Papendorp et al. (2020); A35 – Wan et al. (2021); A36 – Whitney et al. (2019); B1 – Kang et al. (2020); B2 – Joeris et al. (2018); B3 – Alshabi et al. (2022); B4 – Bukhary et al. (2021); B5 – Mulat et al. (2024); B6 – Almalki et al. (2021); B7 – Raza et al. (2021); B8 – V. Kumar et al. (2021); B9 – Tefera et al. (2020); B10 – Brun et al. (2018); B11 – Nagamoto & Kunugita (2023); B12 – Ong et al. (2021); B13 – Barbosa & Silva (2022); B14 – Domienik-Andrzejewska et al. (2018).

Appendix J

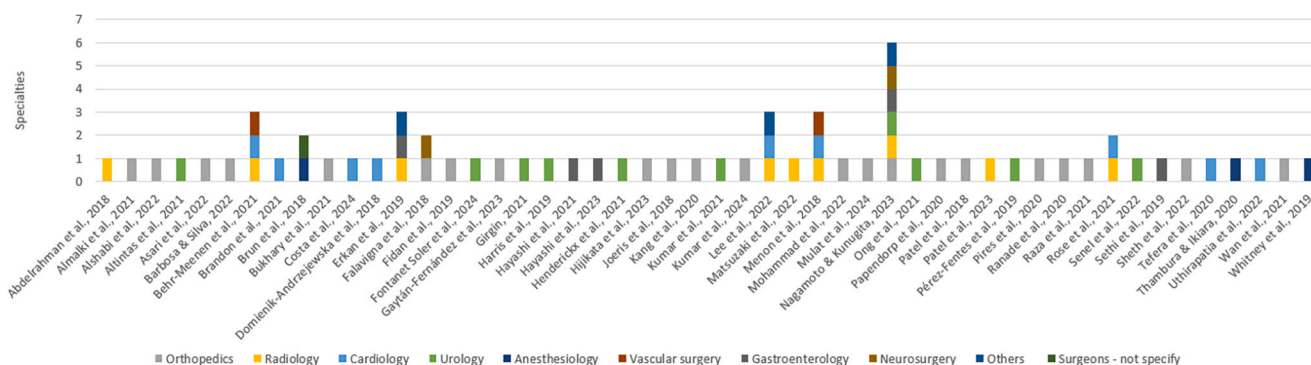
Data collected

Full access is available at: https://docs.google.com/spreadsheets/d/1lDrilSs1aHwNgcOPNavjeZlkREz0CJV/edit?usp=drive_link&ouid=114964709382943245472&rtpof=true&sd=true.

Coi	STUDY					GENERAL INFORMATION										DATA COLLECTION					
	Author(s), Year	Country/Region	Continent	ERI	Focus study	Medical specialt	Profession	Target	Sample	Final sample	Positive rate	Gender (%)	% F	Gender (%)	% F	Age	Year	Period of study	Methodology	Observation	Design site
A14	Abdelrahman et al., 2018	Jordan	Asia	High	To assess compliance with radiation safety practices	Radiology	Radiologists: Residents (12) - Consultants (28)	Twelve tertiary hospitals in two major cities	84	62	74%	48	77%	18	23%	(16-75)-24%	2015	May to June	Yes	Expert validity	Cross-sectional
B6	Almalki et al., 2021	Saudi Arabia	Asia	Very High	To assess the compliance with using radiation protection equipment, as well as assessing the level of knowledge about radiation exposure among the orthopedic OS staff	Orthopedics	-Orthopedic physicians: 76% - OR Nurses: 12% - Radiology technicians: 12	Members of the Saudi Orthopedic Association	ND	242	ND	172	71%	70	29%	ND	2021	January to May	Yes	The questionnaire was developed and validated by Jentzen et al.	Cross-sectional
B3	Alshabi et al., 2022	Saudi Arabia	Asia	Very High	Assess awareness and knowledge about the safety of radiation exposure	Orthopedics	Orthopedic surgeons	Private and governmental hospitals in Al-Madinah city	100	57	57%	50	88%	7	12%	ND	2022	January to March	Yes	The validity of the questionnaire was determined by factor analysis and principal components	Descriptive cross-sectional
A15	Altintas et al., 2021	Turkey	Intercontinental: Asia/Africa	Very High	Evaluate the awareness of the use of fluoroscopy	Urology	Endourologists	University hospitals, public hospitals, education and research hospitals and private hospitals	400	228	57%	ND	ND	ND	ND	ND	2018-2019	May 2018 to April 2020	ND	ND	ND
A16	Asari et al., 2022	Japan	Asia	Very High	To assess attitudes and behaviors toward occupational radiation exposure and investigate the prevalence of occupational radiation-induced skin injury among orthopedic surgeons	Orthopedics	Orthopedics	Orthopedic surgeons - Prefecture in Japan	227	108	48%	ND	ND	ND	ND	ND	2019	April	ND	ND	ND
B13	Barbosa & Silva, 2022	Brazil	America	High	To understand the perception of the risk of exposure to ionizing radiation in fluoroscopy procedures	Orthopedics	Orthopedists and Traumatologists	members of 3 professional societies with email available on the internet	ND	141	ND	119	84%	22	16%	(10-55)-40%	2020	Until November 2nd, 2020	ND	ND	ND
A17	Behr-Meensoo et al., 2021	Germany	Europe	Very High	Investigate the extent to which international recommendations are observed in interventional medicine	- Cardiology - Radiology - Vascular surgery	- Interventional cardiologist (57) - Interventional radiologist (11) - Vascular surgeons (1) - Anesthetists (cardiology and vascular medicine) (12)	Distributed via organizations including the German Cardiac Society, German Society of Germanists	16	104	90%	69	67%	33	23%	41.6(3)	ND	ND	ND	ND	ND
A18	Brandon et al., 2021	Ireland	Europe	Very High	Evaluate knowledge, routine use and concerns	Cardiology	Interventional cardiologist - Trainee	The Irish Cardiac Society "Jigging Meeting"	ND	27	ND	21	78%	6	22%	(10-35)-45%	2018	February	ND	ND	ND

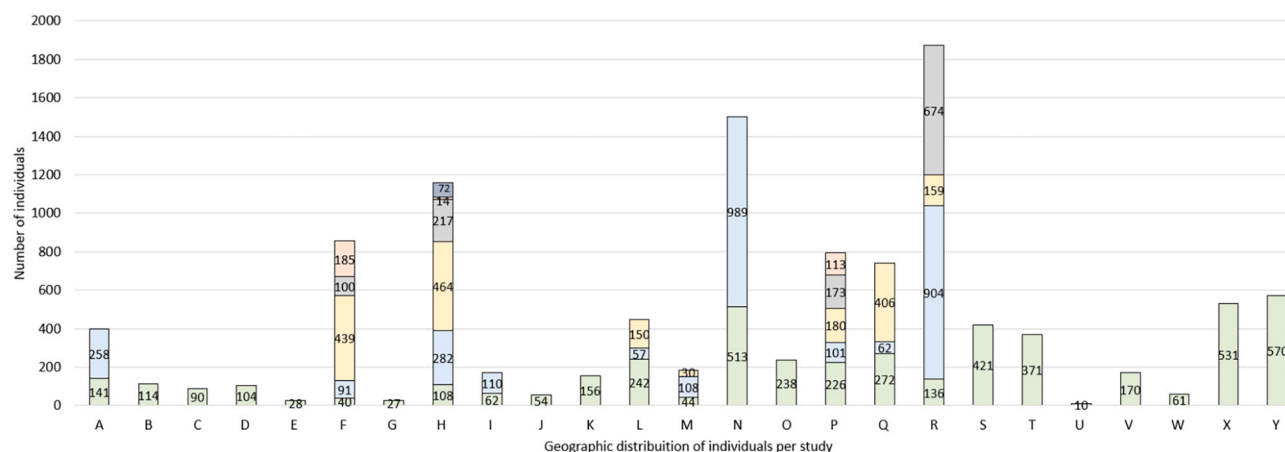
Appendix K

Medical specialties included in each study.



Appendix L

Geographic distribution of individuals per study.

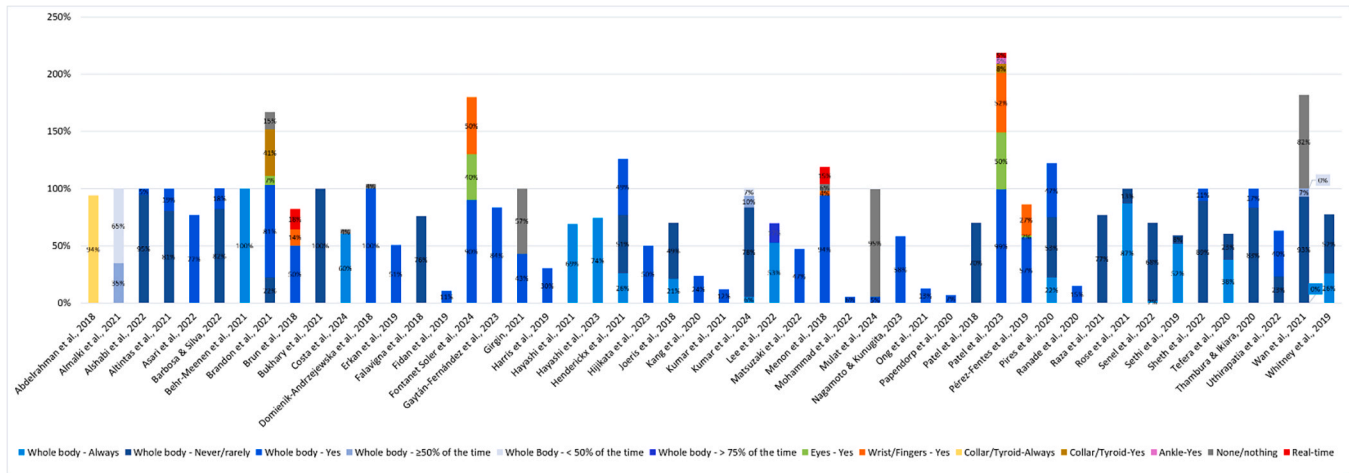


A – Brazil (n = 399; 4 %); B – Ethiopia (n = 114; 1 %); C – France (n = 90; 1 %); D – Germany (n = 104; 1 %); E – Hong Kong (n = 28; 0,3%); F – India (n = 855; 8 %); G – Ireland (n = 27; 0.2 %); H – Japan (n = 1157; 11 %); I – Jordan (n = 172; 2 %); J – Mexico (n = 54; 1 %); K – Portugal (n = 156; 1 %); L – Saudi Arabia (449 individuals; 4 %); M – South Africa (n = 182; 2 %); N – South Korea (n = 1502; 14 %); O – Spain (n = 238; 2 %); P – Turkey (n = 793; 7 %); Q – United Kingdom (n = 740; 7 %); R – United States America (n = 1873; 17 %); S – Belgium, Germany, Greece, France, Italy,

Luxembourg, Norway, Poland, Portugal, and Serbia (n = 421; 4 %); T – Latin America (Brazil, Mexico, Argentina, Colombia, Chile, Peru, Venezuela, Ecuador, Bolivia, Costa Rica, Dominican Republic, Guatemala Paraguay Panama, Cuba, Uruguay, Honduras) (n = 371, 3 %); U – Spain, France, Italy, United Kingdom, Austria, Belgium, Greece and Switzerland (n = 10; 0.1 %); V – Belgium and the Netherlands (n = 170; 2 %); W – Egypt, Sudan, Ethiopia, Kenya, Uganda, Tanzania, Botswana, South Africa, Cameroon, Nigeria, Senegal, Tunisia and Mozambique (n = 61; 0.6 %); X – Africa, Asia-Pacific, Europe, Latin America, Middle East and North America (n = 531; 5 %); Y – USA, Asia, Europe, Canada, Mexico and Central America (n = 570; 5 %).

Appendix M

Individual monitoring dosimeters analyzed in each study.



Appendix N. . Analysis of methodological quality (Joanna Briggs Institute checklist prevalence studies)

Studies (author, year of publication)		Questions									Result per study		
		Q1.	Q2	Q3.	Q4.	Q5.	Q6.	Q7.	Q8.	Q9.	Yes (n)	Yes (%)	Rank
A14	Abdelrahman et al., 2018	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	8	89 %	High
B6	Almalki et al., 2021	Yes	Yes	Yes	No	Yes	Yes	Unclear	Yes	Unclear	6	67 %	Moderate
B3	Alshabi et al., 2022	Yes	Unclear	Unclear	No	Unclear	Yes	Unclear	Yes	Yes	4	44 %	Moderate
A15	Altintas et al., 2021	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A16	Asari et al., 2022	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
B13	Barbosa & Silva, 2022	Yes	Yes	Yes	Yes	Unclear	Unclear	Unclear	Yes	Unclear	5	56 %	Moderate
A17	Behr-Meenen et al., 2021	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
A18	Brandon et al., 2021	Yes	Yes	Unclear	Yes	Unclear	Unclear	Unclear	Yes	Unclear	4	44 %	Moderate
B10	Brun et al., 2018	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
B4	Bukhary et al., 2021	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A1	Costa et al., 2024	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
B14	Domienik-Andrzejewska et al., 2018	Yes	Yes	Unclear	Unclear	Unclear	Yes	Yes	Yes	Unclear	5	56 %	Moderate
A19	Erkan et al., 2019	Yes	Unclear	Unclear	Yes	Unclear	Unclear	Unclear	Yes	Unclear	3	33 %	Low
A20	Falavigna et al., 2018	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A21	Fidan et al., 2019	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A2	Fontanet Soler et al., 2024	Yes	Unclear	Unclear	No	Unclear	Unclear	Unclear	Yes	Unclear	2	22 %	Low
A3	Gaytán-Fernández et al., 2023	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
A22	Girgin, 2021	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	7	78 %	High
A23	Harris et al., 2019	Yes	Yes	Yes	No	Unclear	Unclear	Unclear	Yes	Unclear	4	44 %	Moderate
A24	Hayashi et al., 2021	Yes	Yes	Yes	Yes	Unclear	Unclear	Unclear	Yes	Unclear	5	56 %	Moderate
A4	Hayashi et al., 2023	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
A25	Henderickx et al., 2021	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	6	67 %	Moderate
A5	Hijikata et al., 2023	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
B2	Joeris et al., 2018	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
B1	Kang et al., 2020	Yes	Yes	Yes	No	Unclear	Unclear	Unclear	Yes	Unclear	4	44 %	Moderate
B8	Kumar et al., 2021	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	8	89 %	High
A6	Kumar et al., 2024	Yes	Yes	Yes	No	Yes	Yes	Unclear	Yes	Yes	7	78 %	High
A9	Lee et al., 2022	Yes	Yes	Yes	Yes	Unclear	Unclear	Unclear	Yes	Unclear	5	56 %	Moderate
A10	Matsuzaki et al., 2022	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
A27	Menon et al., 2018	Yes	Unclear	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A8	Mohammad et al., 2022	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
B5	Mulat et al., 2024	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
B11	Nagamoto & Kunugita, 2023	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High

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Studies (author, year of publication)		Questions									Result per study		
		Q1.	Q2	Q3.	Q4.	Q5.	Q6.	Q7.	Q8.	Q9.	Yes (n)	Yes (%)	Rank
B12	Ong et al., 2021	Yes	Yes	Yes	Yes	Unclear	No	Unclear	Yes	Unclear	5	56 %	Moderate
A34	Papendorp et al., 2020	Yes	Yes	Yes	No	Yes	No	Unclear	Yes	Yes	6	67 %	Moderate
A26	Patel et al., 2018	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A7	Patel et al., 2023	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A29	Pérez-Fentes et al., 2019	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A28	Pires et al., 2020	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A30	Ranade et al., 2020	Yes	Yes	Yes	No	Yes	No	Unclear	Yes	Yes	6	67 %	Moderate
B7	Raza et al., 2021	Yes	Yes	Yes	No	Unclear	No	Unclear	Yes	Unclear	4	44 %	Moderate
A31	Rose et al., 2021	Yes	No	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A11	Senel et al., 2022	Yes	Unclear	Unclear	No	Yes	Unclear	Unclear	Yes	Yes	4	44 %	Moderate
A32	Sethi et al., 2019	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A12	Sheth et al., 2022	Yes	Yes	Yes	No	Unclear	Unclear	Unclear	Yes	Unclear	4	44 %	Moderate
B9	Tefera et al., 2020	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
A33	Thambura & Ikiara, 2020	Yes	No	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A13	Uthirapathia et al., 2022	Yes	Unclear	Yes	No	Yes	Unclear	Unclear	Yes	Yes	5	56 %	Moderate
A35	Wan et al., 2021	Yes	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Yes	6	67 %	Moderate
A36	Whitney et al., 2019	Yes	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	7	78 %	High
Total	Yes	100 %	84 %	88 %	48 %	74 %	12 %	2 %	100 %	74 %	5,8	65 %	Moderate
	No	0 %	4 %	0 %	50 %	0 %	12 %	4 %	0 %	0 %			
	Unclear	0 %	12 %	12 %	2 %	26 %	76 %	92 %	0 %	26 %			
	Result per question	Low	Low	Low	Moderate	Moderate	High	High	Low	Moderate			

Note: Adapted from [24,26,44,45,128] Y = yes; N = no; U = uncertain; Low risk of bias = (7–9 'yes' – [78 %–100 %]); Moderate risk of bias = (4–6 'yes' – [34 %–77 %]); High risk of bias (0–3 'yes' – [0 %–33 %])

Low methodological quality (0–3); Moderate methodological quality (4–6); High methodological quality (7–9)

Q1. “Was the sample frame appropriate to address the target population?”

Q2. “Were study participants sampled appropriately?”

Q3. “Was the sample size adequate?”

Q4. “Were the study subjects and the setting described in detail?”

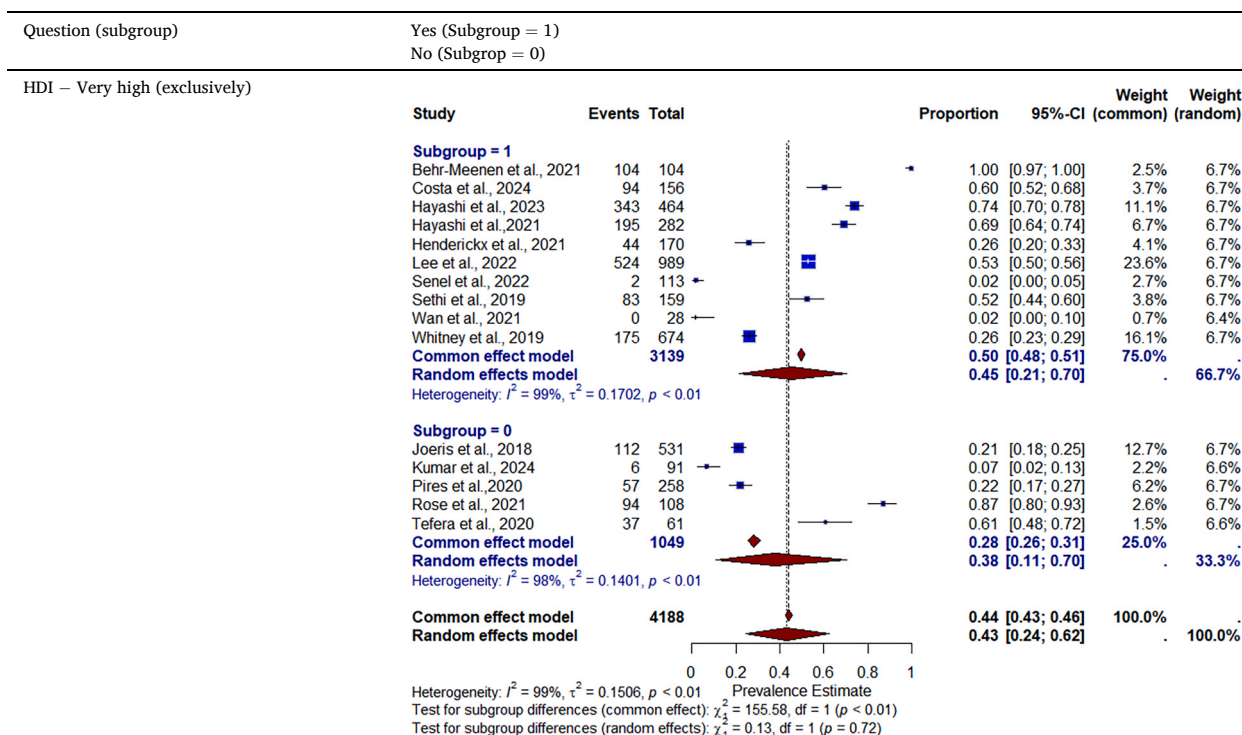
Q5. “Was the data analysis conducted with sufficient coverage of the identified sample?”

Q6. “Were valid methods used for the identification of the condition?”

Q7. “Was the condition measured in a standard, reliable way for all participants?”

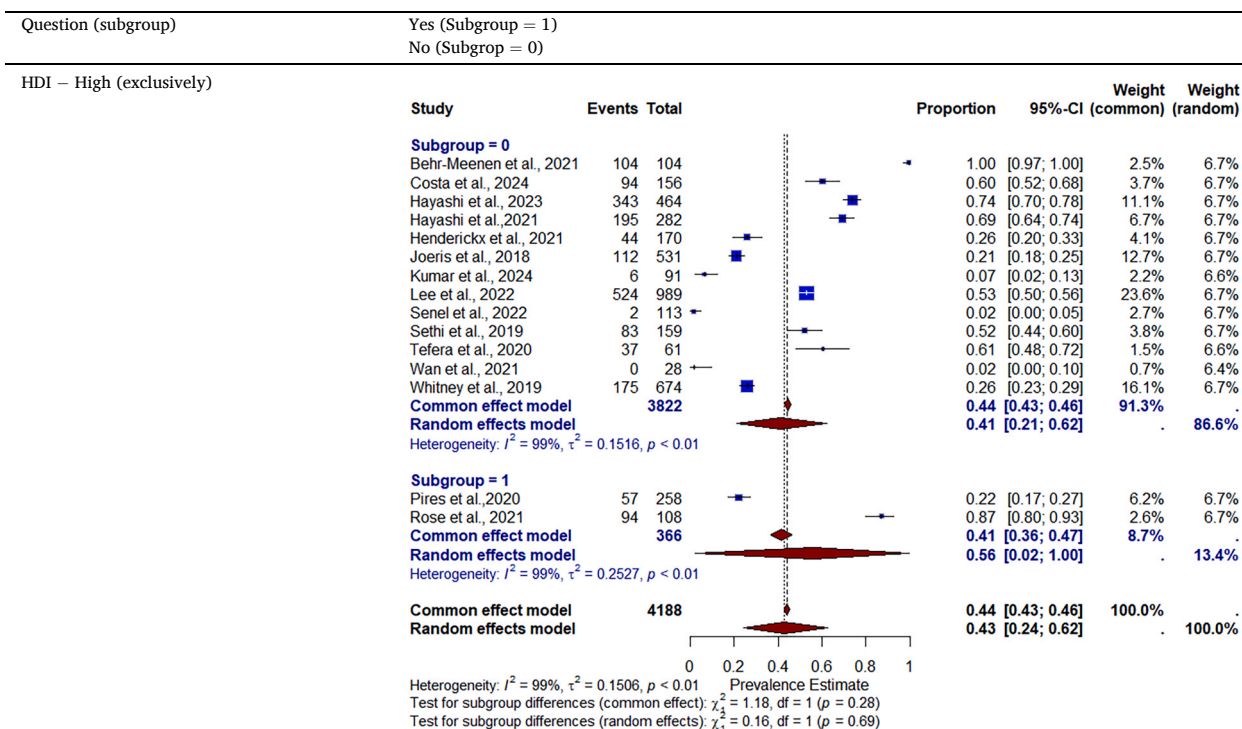
Q9. “Was there appropriate statistical analysis?” Q8. Was the response rate adequate, and if not, was the low response rate managed appropriately?”

Appendix O. . Subgroups in this meta-analysis

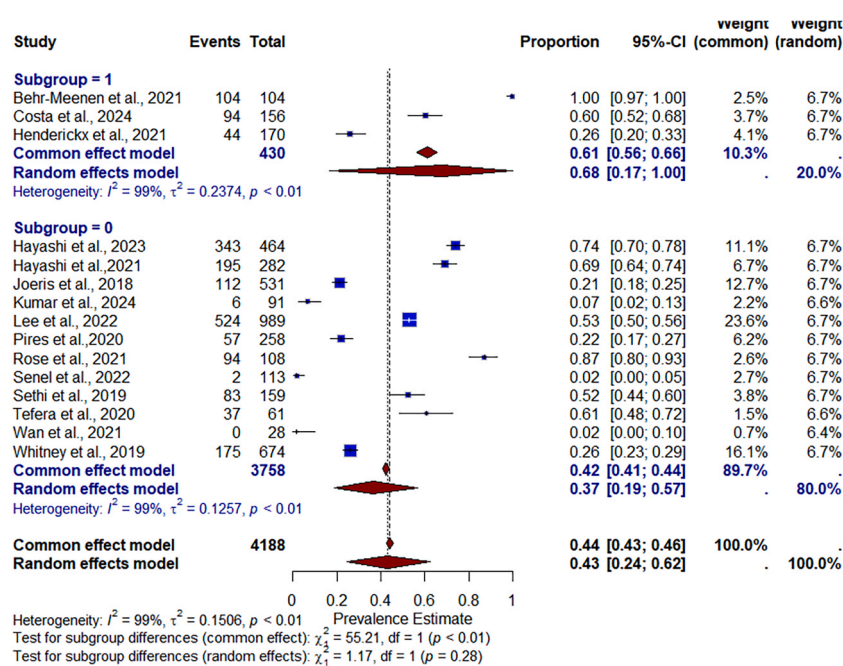


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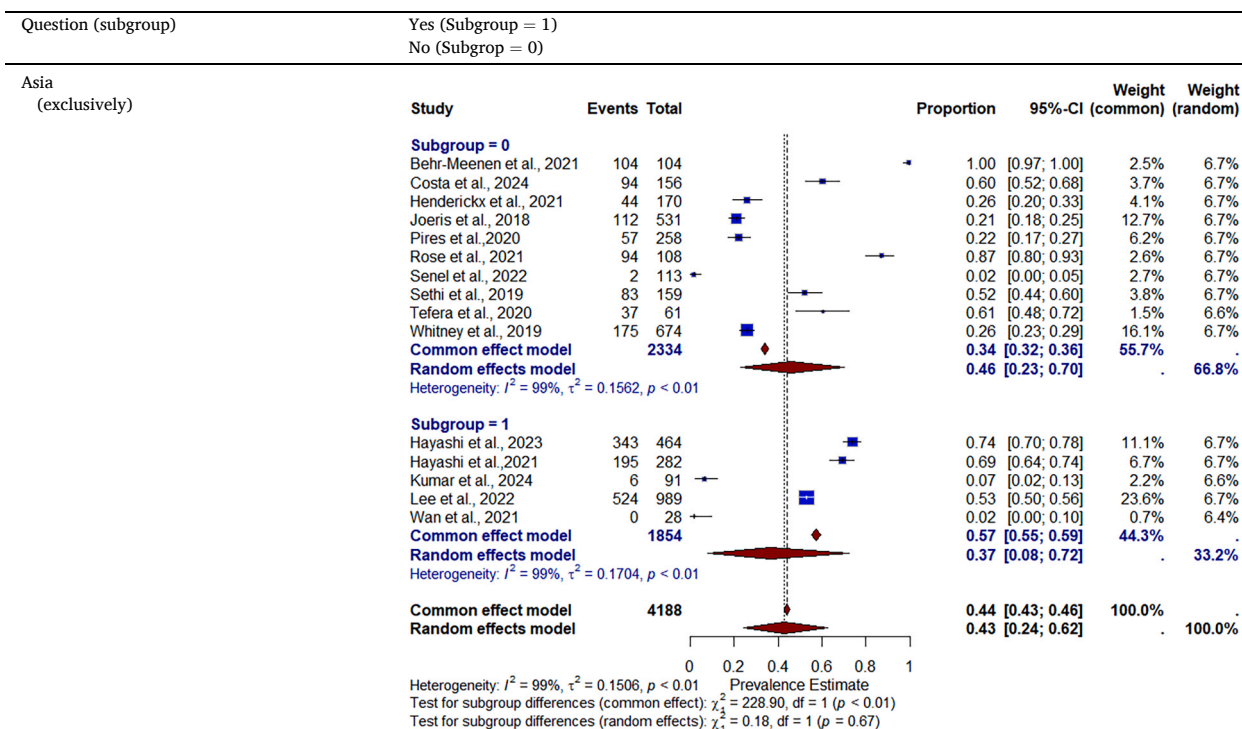
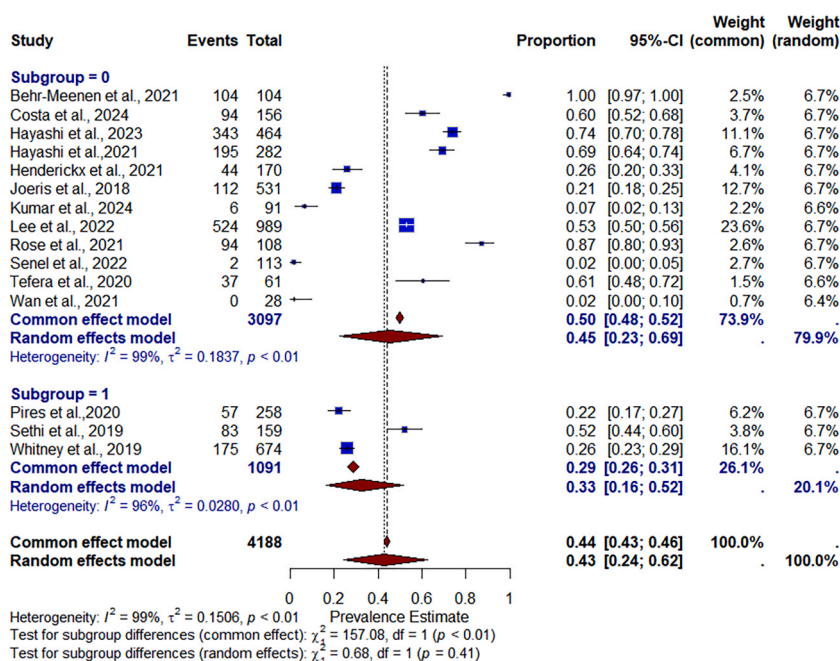


Europe (exclusively)



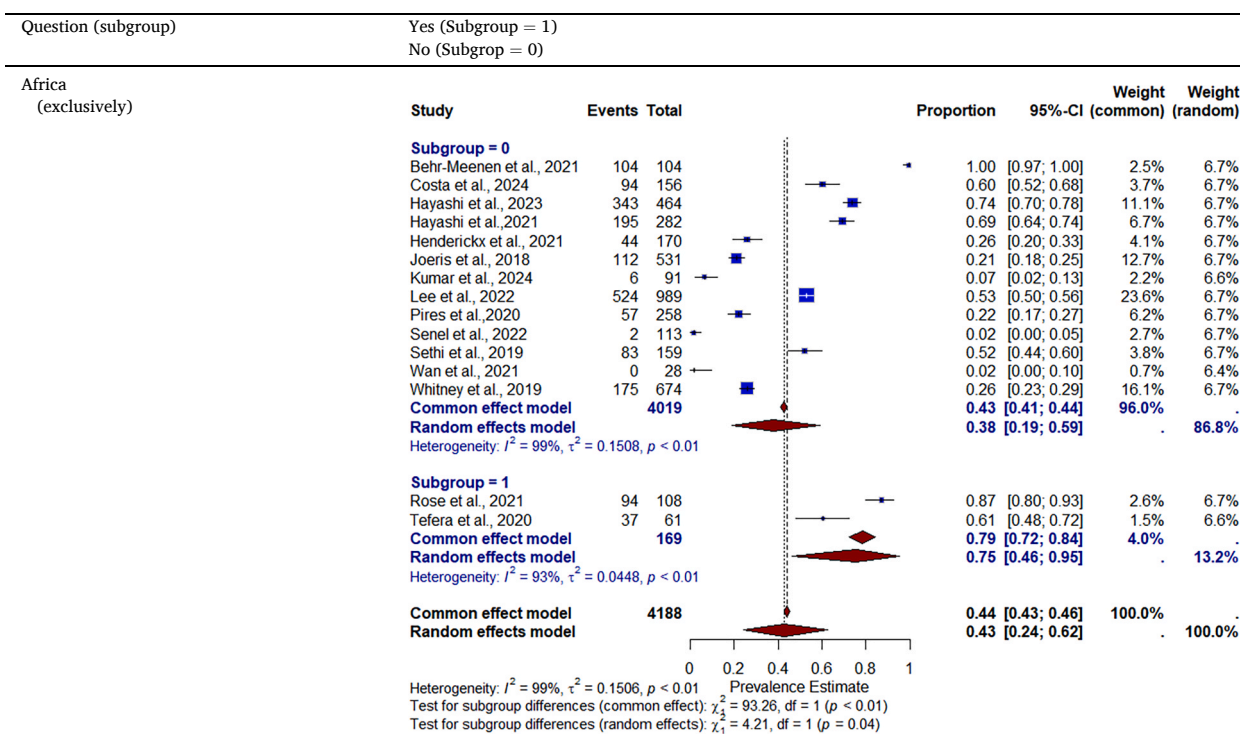
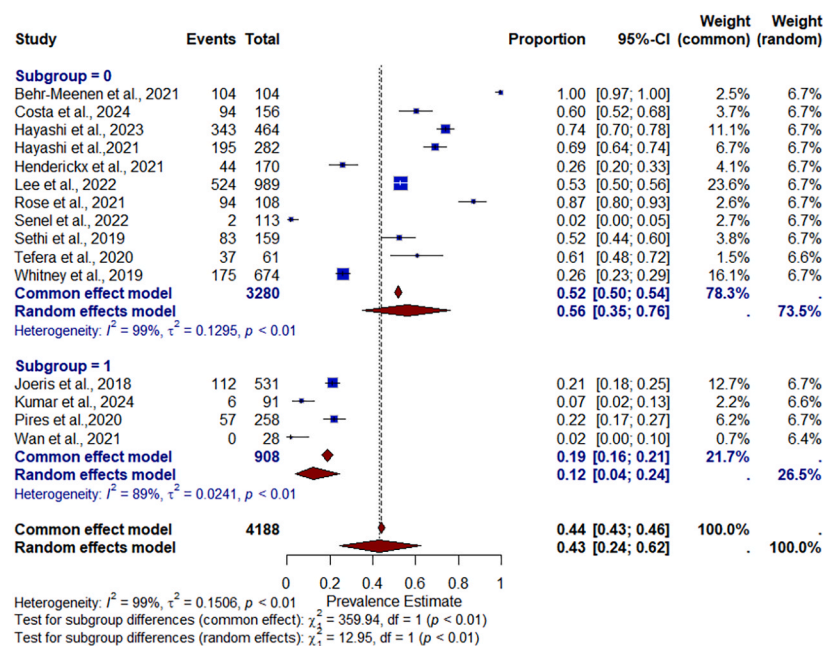
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Americas
(exclusively)

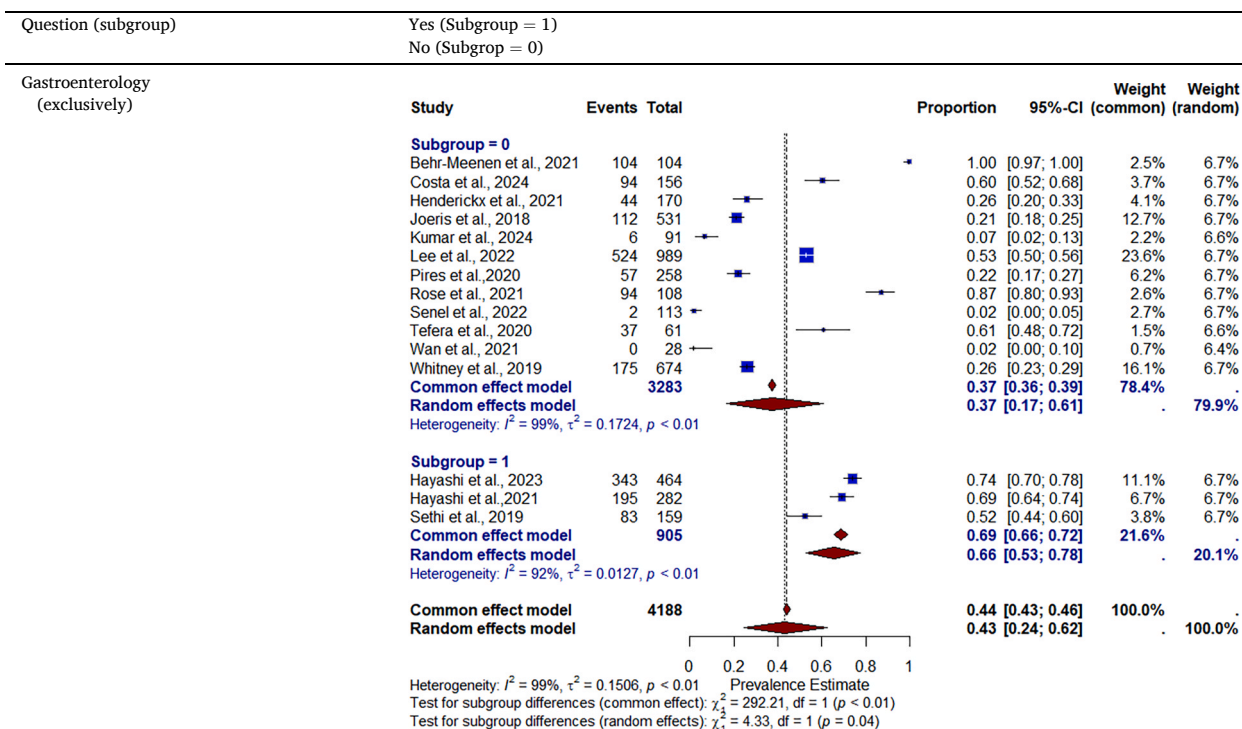
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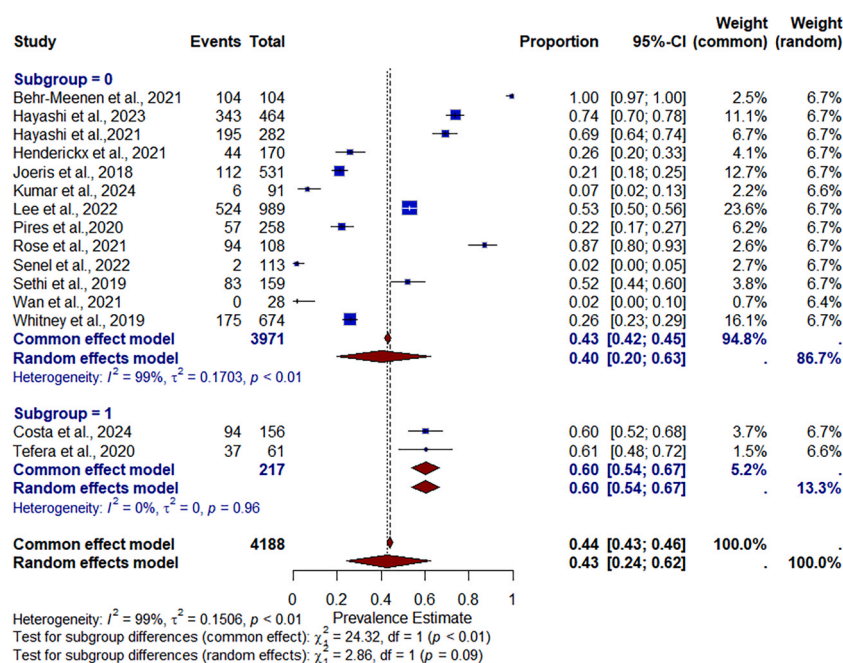
Orthopedics
(exclusively)

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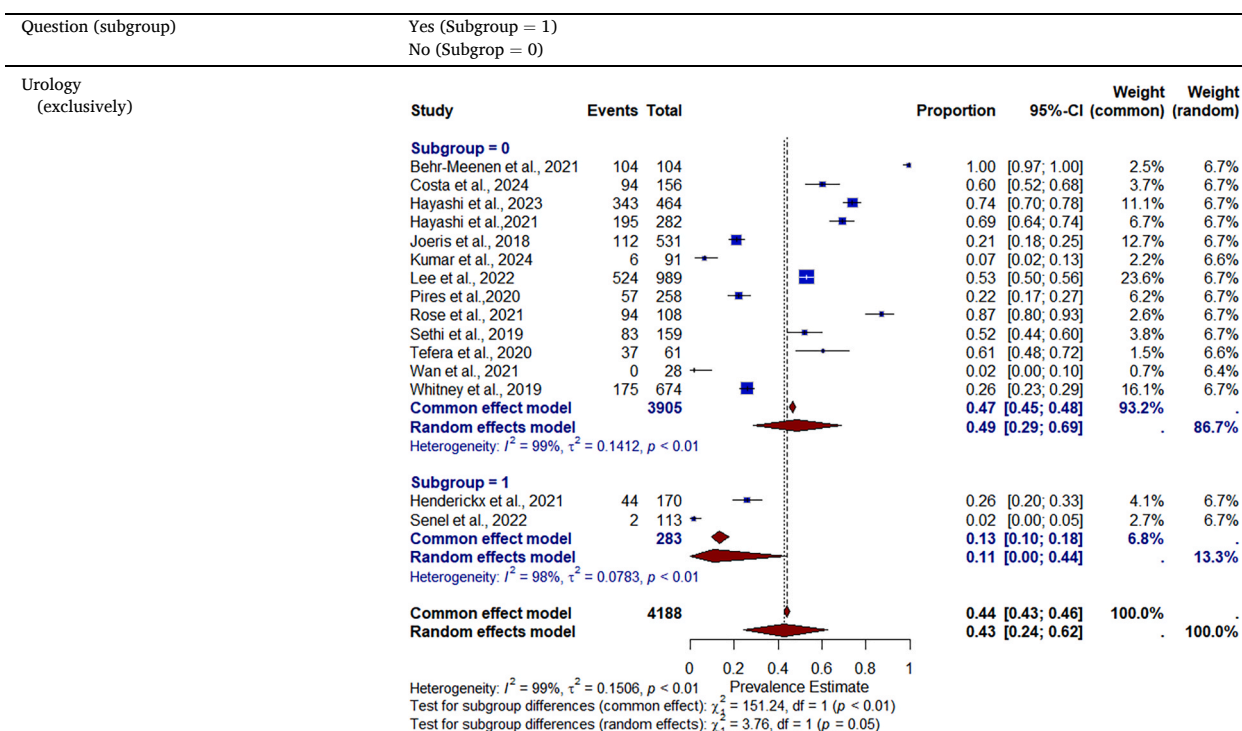


Cardiology (exclusively)

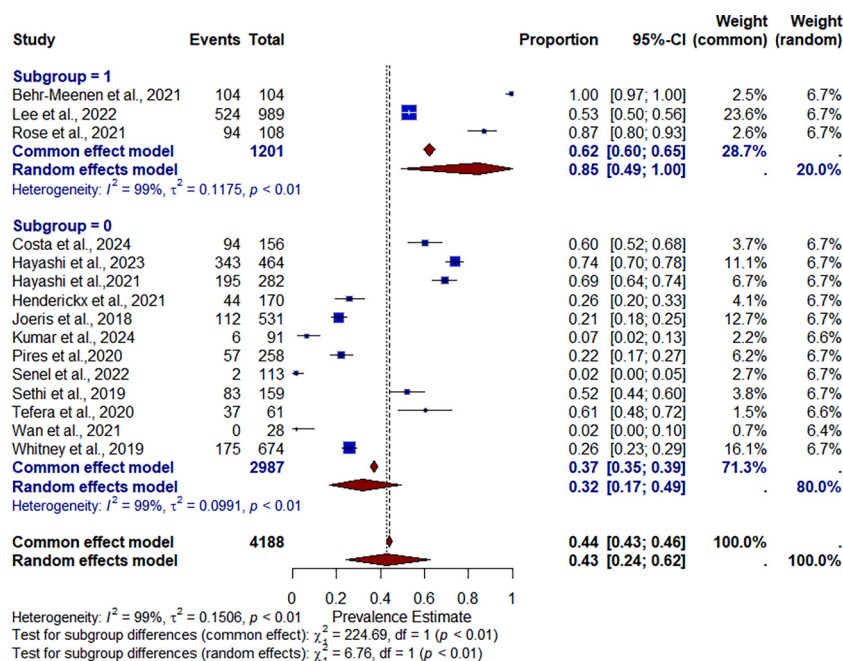


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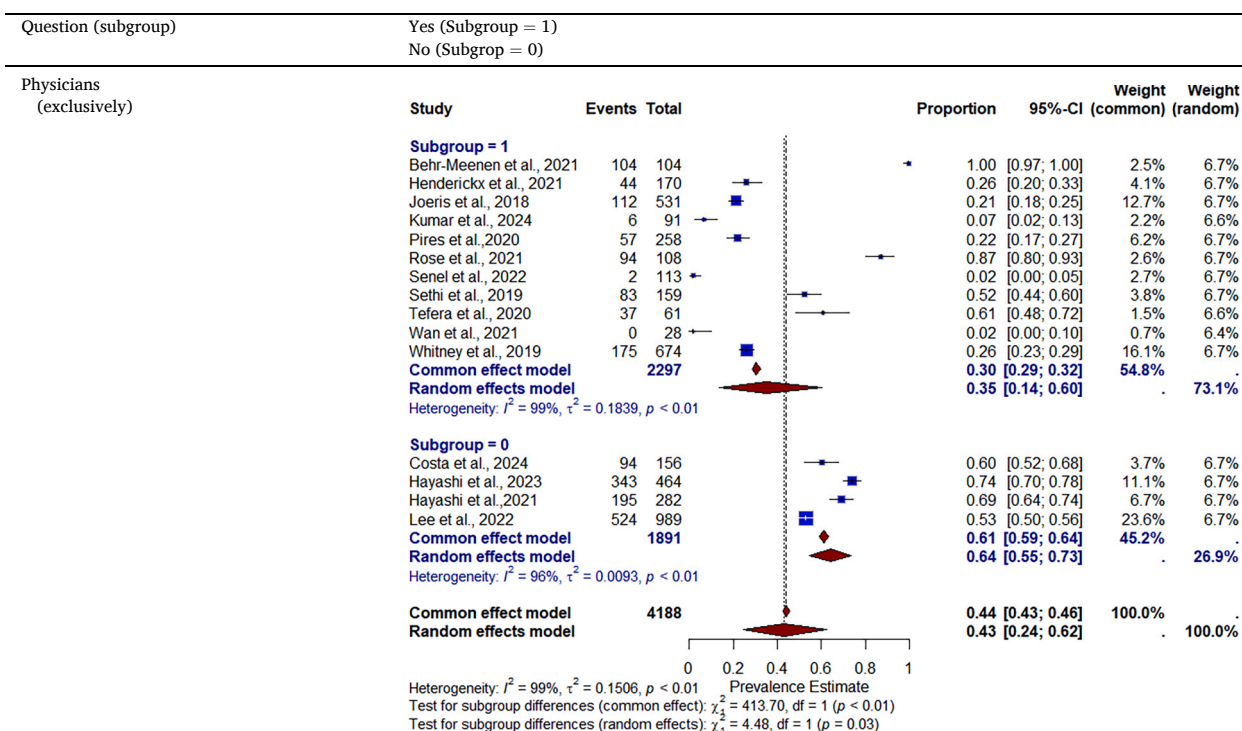


Contains Radiology

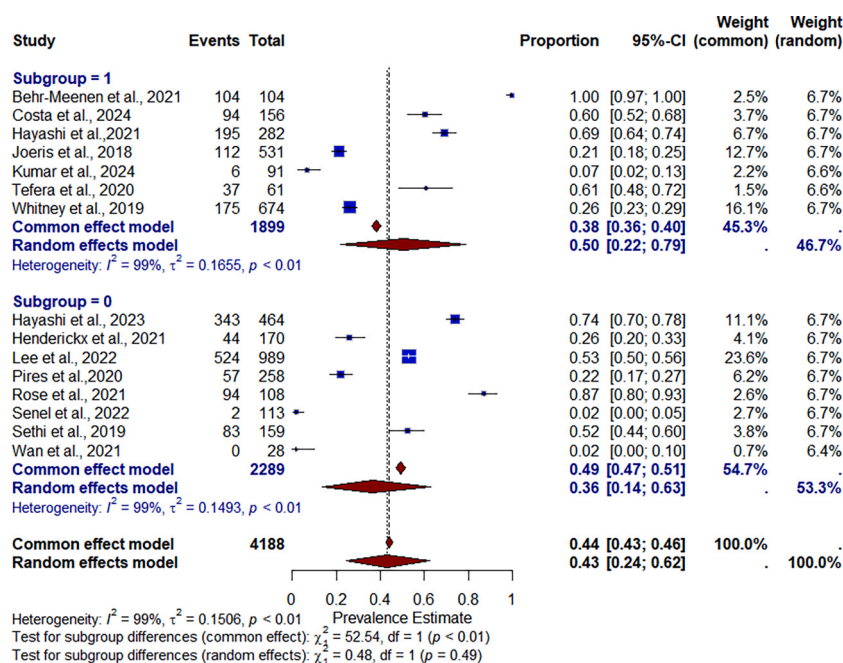


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Methodological quality – High



References

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