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Review

Occupational Exposure to Solar Ultraviolet Radiation: A Systematic Review of Protective Measures

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Abstract

Solar ultraviolet radiation (UVR) is classified as a Group 1 carcinogen and poses a significant occupational hazard to outdoor workers. Despite preventive guidelines, adherence to protective measures remains inconsistent. This systematic review identified the protective measures adopted by healthy outdoor workers and assessed their adherence to and the effectiveness of these measures. Following the PRISMA 2020 statement, the review searched Scopus, Web of Science, and PubMed for peer-reviewed studies published between 2015 and 2025. Eligible studies included at least 100 healthy participants and evaluated preventive or protective measures against solar UVR. Independent reviewers extracted data and assessed risk of bias using the McMaster Critical Review Form. From 17,756 records, 51 studies met the inclusion criteria after screening and a subsequent snowballing process. The identified protective strategies clustered into physical, behavioural, and organisational categories. Adherence ranged from low to moderate, with structured interventions and employer support improving compliance. Sunscreen use remained low due to perceived inconvenience and lack of provision. Overall, the evidence revealed substantial variability in implementation and effectiveness across occupations. Strengthened regulations and integrated interventions combining education, personal protective equipment, and organisational measures are essential. Future research should prioritise longitudinal designs and objective indicators such as biomarkers and dosimetry.

Keywords: occupational exposure; solar ultraviolet radiation; outdoor workers; prevention; personal protective equipment; systematic review

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1. Introduction

Ultraviolet radiation (UVR) is classified as a Group 1 carcinogenic physical agent by the International Agency for Research on Cancer (IARC). It is widely recognised as a leading environmental and occupational health hazard [1]. Prolonged, unprotected exposure to UVR is consistently associated with a range of adverse effects, including sunburn, premature skin ageing, actinic keratoses, cataracts, and, of particular concern, the development of skin cancers such as basal cell carcinoma, squamous cell carcinoma, and malignant melanoma [2,3].

These risks are especially relevant in outdoor work, where cumulative exposure during working hours often exceeds thresholds considered safe by occupational health authorities [4]. Professions in construction, agriculture, fishing, gardening and transport are among those with the most UVR exposure, as demonstrated by numerous studies [4,5]. Despite the solid scientific understanding of the risks, effective implementation of preventive measures in real-world settings remains challenging, often hindered by operational and socio-cultural factors [6].

Recommended protection strategies include wearing appropriate clothing, using wide-brimmed hats, applying sunscreen with an adequate sun protection factor (SPF), rescheduling work to avoid peak solar radiation hours, and participating in awareness programmes promoting protective behaviours [7,8]. The real-world effectiveness of these measures varies significantly, depending on individual compliance, the suitability and availability of equipment, the training provided, and the professional and cultural context in which such strategies are implemented [9–11]. More recently, emerging digital technologies have been explored as complementary tools for preventing and monitoring occupational solar UVR exposure. These include smartphone-based applications providing real-time UV index information, behavioural prompts, and exposure alerts, as well as wearable or portable intelligent monitoring systems capable of estimating individual erythemal UV doses during outdoor work activities. Although these approaches show promise in supporting risk awareness and preventive decision-making, their integration into occupational health practice remains limited and uneven, highlighting the need for further evaluation and validation in real-world occupational settings [12,13].

Outdoor workers are therefore at increased risk due to the combined effects of extreme heat and UVR exposure, highlighting the need for more robust and adaptive preventive approaches [14]. This evolving reality necessitates regulatory updates and a re-valuation of workplace practices, particularly in regions where environmental variables are not yet fully considered in occupational health planning [6].

At the same time, growing attention from occupational health and safety authorities has fuelled debate around the formal recognition of solar UVR exposure as a legitimate occupational hazard. Nonetheless, many countries still lack specific legislation establishing exposure limits for natural solar radiation. It is important to note that proposed exposure limits and preventive recommendations for outdoor workers should be interpreted as reference values rather than universally applicable thresholds. Latitude, climatic conditions, seasonal variability, and local working practices highly influence occupational exposure to solar UVR. Consequently, preventive strategies and exposure benchmarks require contextual adaptation to regional and environmental conditions, as well as to workforce characteristics, rather than a one-size-fits-all application [15].

In Portugal, for instance, current legislation, notably Portuguese Law no. 25/2010 of 30 August, which transposes the European Directive 2006/25/EC, sets occupational exposure limits only for artificial UVR sources, leaving solar radiation unregulated [16]. This regulatory gap results in the absence of mandatory guidance on protective measures, undermining employer accountability and compromising worker protection. It is therefore essential to produce solid scientific evidence to support the development of technical standards and public policies in this area [17].

Against this backdrop, the present systematic review aims to identify and characterise the protective measures used by outdoor workers in various professional contexts to mitigate exposure to solar UVR. The findings will support the development of more effective preventive strategies to reduce the incidence of occupational diseases related to sun exposure. Furthermore, in accordance with the PRISMA 2020 statement [18], this review consolidates current knowledge and identifies key research gaps to inform future studies and occupational health interventions. To enhance the robustness and public health relevance of the synthesis, predefined eligibility criteria were applied, including a minimum sample size threshold, as detailed in the Section 2.

2. Materials and Methods

The methodology applied in this systematic review to protective measures against occupational exposure to UVR adhered to the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, revised in 2020. The first version of this systematic review methodology emerged in 2009, initially within the field of health. However, its recognition and applicability in other scientific areas were notable, leading to improvements in 2015 and, more recently, 2020 [18]. The PRISMA 2020 Checklist for this systematic review is available as supplementary material.

2.1. Selection and Identification Process

This review included original studies involving healthy human participants that focused on occupational exposure to solar-origin ultraviolet radiation and assessed protective or preventive measures in workplace settings. Only peer-reviewed journal articles published in English, with sample sizes of 100 or more participants, were considered to enhance the robustness and external validity of the descriptive synthesis and to reduce the influence of small exploratory or pilot studies. This review excluded review articles, conference abstracts, studies involving populations with UV-related pathologies, non-human or post-mortem data, artificial materials, and studies that did not directly address protective methods. A language restriction to English was applied to ensure consistency in data extraction and interpretation, although this is acknowledged as a limitation in terms of global coverage.

The search was conducted on 9 March 2025 using the electronic databases Scopus, Web of Science (all collections), and PubMed. Boolean expressions incorporating terms such as "ultraviolet radiation", "solar UV", "occupational", "outdoor", "workplace", "protection", "prevention", and "PPE", among other synonyms, were structured using "AND" and "OR" operators, as detailed in Appendix A (Table A1). The identified articles entered the Rayyan platform, which removed duplicate records. The process then screened titles and abstracts, followed by a review of full texts.

This review consistently applied the inclusion and exclusion criteria at all stages of screening. It retained articles that raised doubts for full-text evaluation. After the reading, it selected only studies that fulfilled all the requirements and documented and justified all exclusions accordingly.

Two reviewers independently conducted study selection (R.R. and C.C.). In cases of discrepancy, they reached a decision by consensus and consulted a third reviewer when necessary (J.S.B.). They retrieved the included studies from their sources and extracted the relevant data into a shared Excel spreadsheet. Both reviewers validated the extraction process.

A complementary manual snowballing search was also performed, both backwards (reference lists of included studies) and forward (articles citing the included studies) [19]. Additional articles identified through this method were subject to the same inclusion and screening criteria.

This review synthesised the extracted data in a comprehensive summary table, aligned with its objectives. The Section 3 (Appendix A, Table A2) categorises the studies

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by professional category and UVR protection method. The table presents the type of UVR measurement method used, the specific protective measures evaluated, the level of adherence to each measure (low, moderate, high, or not reported), and the main findings from each study. The level of adherence to each protective measure was extracted from the original studies as reported. When quantitative data were available, adherence was classified according to the proportion of workers reporting regular or consistent use of the measure. In studies reporting qualitative or categorical information, adherence levels were classified as low, moderate, or high based on the authors' descriptions, thresholds, or reported frequencies. When insufficient information was provided, adherence was recorded as "not reported". The table does not present author, year, and country variables in separate columns, but readers can identify them through the corresponding study references. This structure enables a thematic and comparative analysis of protective behaviours across occupational groups.

In addition, this review complements the presentation of results with visual elements, including a map showing the geographical distribution of studies, a graph of the number of publications per year, and a bar chart representing the journal quartile rankings based on the Scimago Journal Rank [20].

This review did not conduct a meta-analysis, as the main objective was to qualitatively systematise the protective measures used by workers across different occupational sectors. Although it did not perform a quantitative synthesis, it explored patterns of heterogeneity across geographical regions, professional groups, and study designs, as reflected in the descriptive synthesis.

This review complemented the information obtained by assessing the quality of the publication sources, including the journal quartile classification using Scimago Journal Rank [20]. Consequently, the review did not conduct a formal confidence assessment of the evidence, as the substantial methodological heterogeneity across the included studies precluded the use of standardised frameworks. Given its qualitative scope and objectives, the review considered a formal certainty assessment methodologically unfeasible and misaligned with the intended synthesis, which focused on descriptive and thematic interpretation rather than quantitative aggregation.

2.2. Risk of Bias Assessment

The Critical Review Form: Quantitative Studies, developed by McMaster University [21], was used to evaluate the risk of bias in the studies included in this systematic review. This tool enables a detailed examination of fundamental methodological aspects, including study design, sampling and population characterisation, variable validity, and the appropriateness of statistical methods. It also evaluates clarity in the description of interventions, transparency in handling losses to follow-up, and adherence to ethical procedures such as informed consent. Appendix A—Figure A1 presents the questions used to assess the risk of bias.

Two reviewers independently conducted the risk of bias assessment and consulted a third reviewer in the event of disagreement.

Given the descriptive and qualitative nature of this systematic review, as well as the substantial methodological heterogeneity among the included studies, we did not formally assess the certainty of the evidence. Instead, we focused the synthesis on identifying and characterising protective strategies against occupational exposure to solar UVR, rather than quantifying the effectiveness of interventions. Therefore, we considered a certainty assessment methodologically unfeasible and misaligned with the objectives of this review. Nevertheless, we duly considered the identified methodological limitations during the analysis and interpretation of the results.

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3. Results

3.1. Study Selection

The study selection process followed the PRISMA 2020 protocol guidelines [18]. Figure 1 presents the adapted flow diagram, clearly and sequentially illustrating all stages undertaken during the identification, screening, eligibility assessment, and final inclusion of studies in this systematic review.

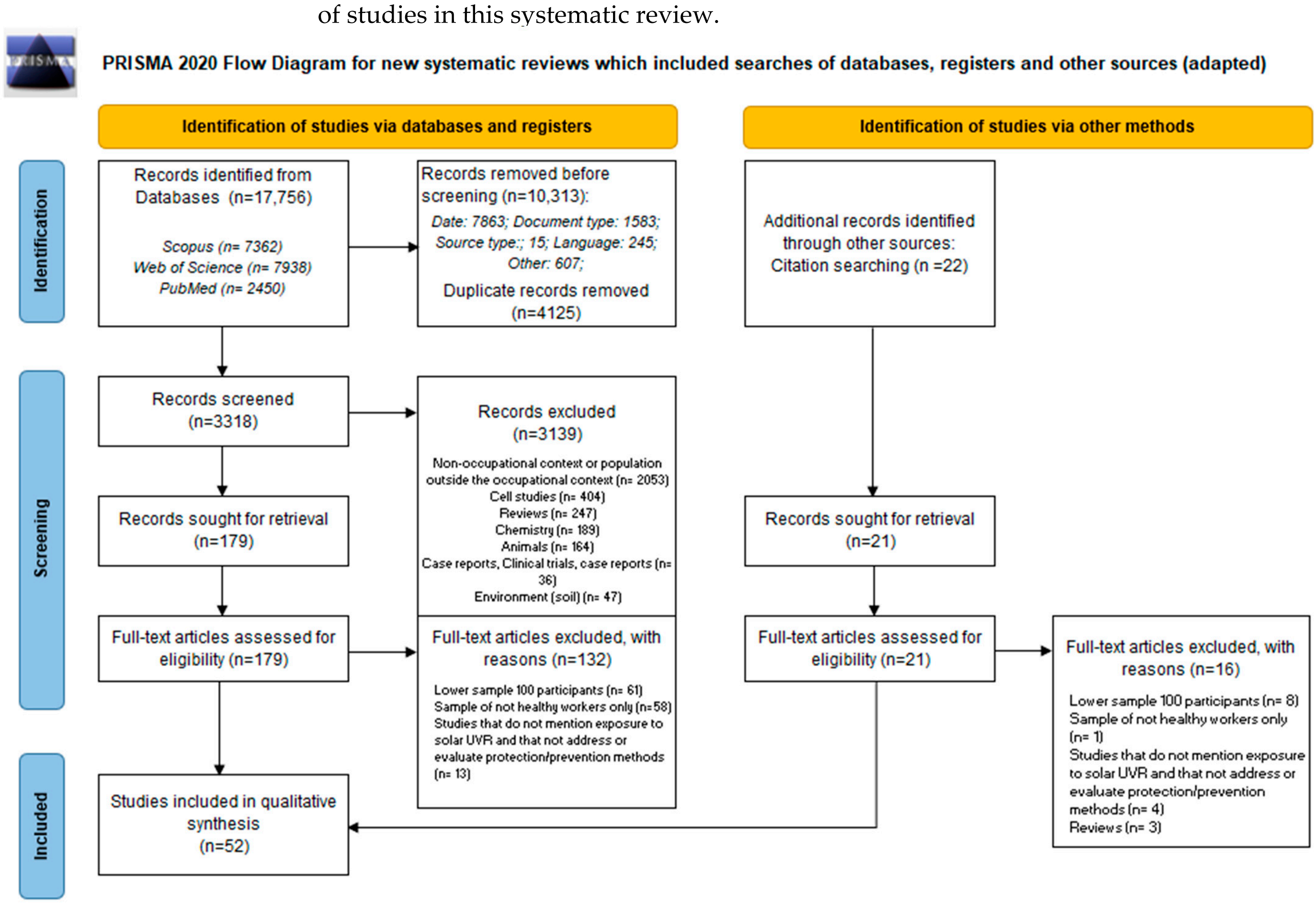

Figure 1. Flow diagram of the study selection process, adapted from Page et al. (2021) [18].

This review searched the literature in the electronic databases Scopus, Web of Science, and PubMed, as detailed in the Section 2, and identified 17,756 records. After applying the initial exclusion criteria—publication date range (2015–2025), document type (scientific articles), and language (English)—the review excluded 10,313 records. It automatically removed 4125 duplicates, leaving 3318 articles for title and abstract screening.

At this stage, the review excluded 3139 articles that did not align with its objectives or failed to meet the eligibility criteria, and it selected 179 articles for full-text assessment. Following detailed evaluation, the review excluded 132 articles based on specific reasons: 61 for including samples with fewer than 100 participants or lacking information about the sample, 58 for analysing populations with pathologies or lacking confirmation of occupational health, and 13 for not directly evaluating methods of protection or prevention against solar UV radiation exposure.

In addition, the review identified 21 articles through complementary manual snowballing strategies, including direct citations (forward) and reference lists (backwards) of the included studies [19]. After full-text assessment, the review excluded 16 articles: eight due to small sample sizes, one for not involving healthy workers, four for not addressing protective methods, and three for being review articles. As a result, the review included

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52 studies in the qualitative synthesis, which formed the evidence base for the analysis. This review examined these studies in terms of methodological characteristics, occupational group, protective measures evaluated, level of adherence, and key findings. Appendix A—Table A2 summarises the main characteristics of the included studies.

3.2. Study Characteristics

This systematic review included studies published from 2003 to 2025 [22–73], with the majority concentrated between 2015 and 2025 [27–73], consistent with the inclusion criteria. However, due to the snowballing technique described in the previous section, studies published between 2003 and 2011 were also identified [22–26]. Figure 2 shows the chronological distribution of the included articles.

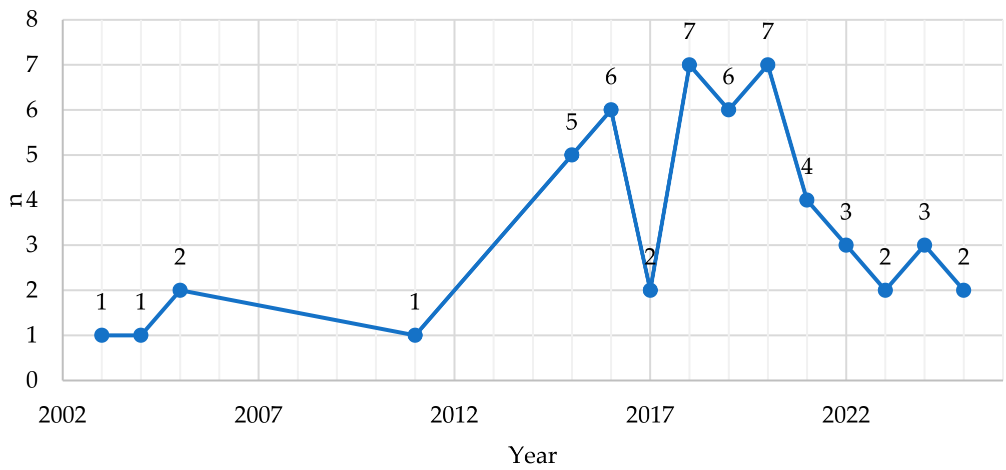

Figure 2. Annual distribution of included studies.

This review also considered the editorial robustness of the included studies, based on journal rankings from the Scimago Journal Rank [20], 23 in Q1 journals [24,26,28,29,32,36,43,45,48,49,52–57,59–61,64,65,71,72], 18 in Q2 journals [22,25,30,31,33–35,38–40,42,44,46,47,62,66,69,70,73], and 10 in Q3 journals [23,27,37,41,50,51,58,63,67,68]. This quality distribution is depicted in Figure 3, indicating the overall methodological soundness of the included studies.

Regarding geographical distribution, most studies were conducted in Europe, totalling 21, with Germany standing out as the country with the highest number of studies included [22,31,33–35,38,40,43,49,53,54,56,60,61,64–66,68,70–73]. In addition to Europe, 20 studies were conducted in North America, primarily in the United States [23,24,26–28,37,39,41,42,44,45,47,48,51,55,57,59,62,63,67]. Furthermore, four studies originated from Asia, including two from Iran, one from China, and one from Turkey [30,36,50,52], as well as two from Brazil [29,69]. Figure 4 illustrates the geographical distribution of the included studies, highlighting the predominance of research in regions with warm climates and high levels of UVR incidence.

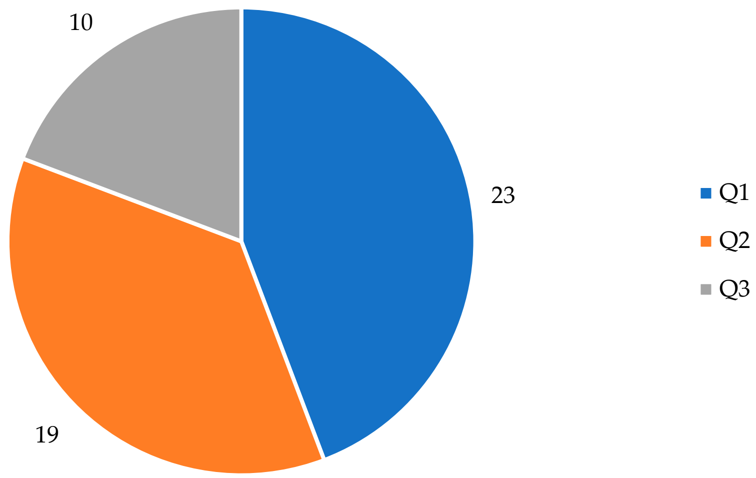

Figure 3. Distribution of journal quartiles for the included studies, using Scimago Journal Rank [21].

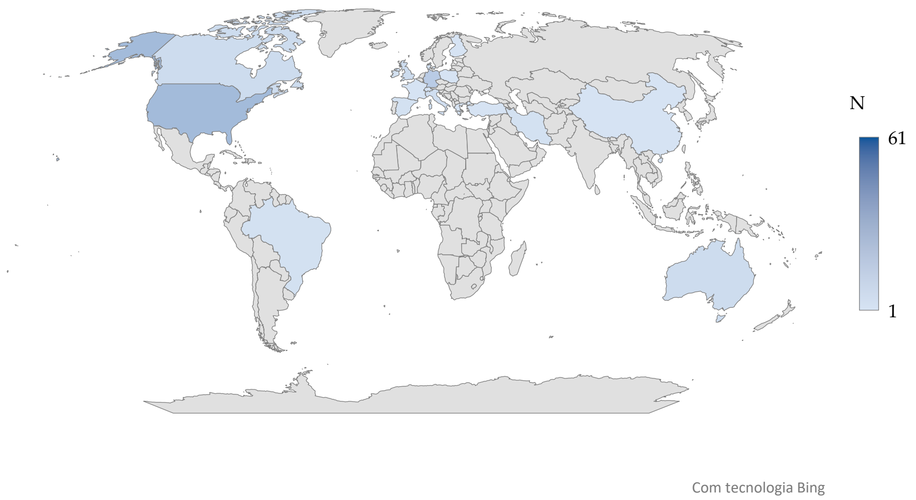

Figure 4. Geographical distribution of the included studies. (Reproduced in Microsoft® Excel® for Microsoft 365 MSO, using Bing technology).

The professional groups addressed in the included studies comprised farmers [23,30,32,33,36,39,47,57,58,60,68,69,71,73], construction workers [22,25,33,35,57,73], gardeners [60,71,73], lifeguards [66], postal workers [26,31], electricians [44], maintenance technicians [24,27,28,34,65], naval and aviation military personnel [41,70,73], mountain guides [61], fishermen [29], municipal workers and street sweepers [44,50], sailors [52], park workers [42], transport workers [45], forestry workers [56], among other outdoor occupations [37,38,40,43,48,49,51,53–56,59,62–64,67,72,73]. This diversity enabled a comparative analysis of distinct occupational realities regarding UVR exposure risk, availability of protective resources, and adherence to preventive behaviours.

Regarding UVR exposure assessment methods, there was a predominance of self-administered questionnaires [22–27,29–43,45–47,50–73]. Dosimetry was also employed [25,43,44,48,49,66], in conjunction with direct observation [23,26,28,59,69], dermatological examinations, and clinical interviews [25,43,50,56,60,65,70].

This review categorised the protective strategies identified in the different studies into three main groups:

- Physical measures: including the use of hats or caps [10,22–28,30,32,34,36–39,42–44,46–48,52,53,55–60,62,64,66–69,72,73], protective clothing [22,23,25–27,31–35,37–49,51–53,55–60,62,64,66–69,71–73], gloves [23,38,42,44,52,58,62,69], sunglasses [22–28,30–32,34,35,37–40,42,44,47,48,50,52,53,55,56,58,59,62,66–68,71,73], and seeking shade [22–25,27,28,30,32–35,37–42,44,45,48,49,51–53,55,56,59,66–68,72,73];
- Behavioural measures: including sunscreen application [22–25,27–43,45–48,50–73], lip balm with sun protection [24,27,37], avoiding exposure during peak UVR hours [22,27,30,32,35,36,52,66,71], taking regular breaks [53], maintaining adequate hydration [22,31,34,35], and performing skin self-examinations [22,27,35,45,51,52,60,61,65,67,69,70];
- Organisational measures: encompassing worker training programmes [28,33,34,45,51,53,59,72], internal policy reviews [67], and adjustments to work schedules [37,43,49,51,56,62,64,67,72].

Among these, the most frequently reported protection measures were the use of hats or caps, sunscreen application, and protective clothing, reflecting their widespread recommendation in occupational health guidelines.

Additionally, the studies referenced other protective initiatives, such as sun protection reminders [59], communication of best practices and UVR risk [28,45,59], and UV index monitoring [38,45,67].

These data enable a comparative analysis of the preventive approaches employed in various occupational contexts. Figure 5 presents the frequency of UVR protection strategies assessed in the included studies.

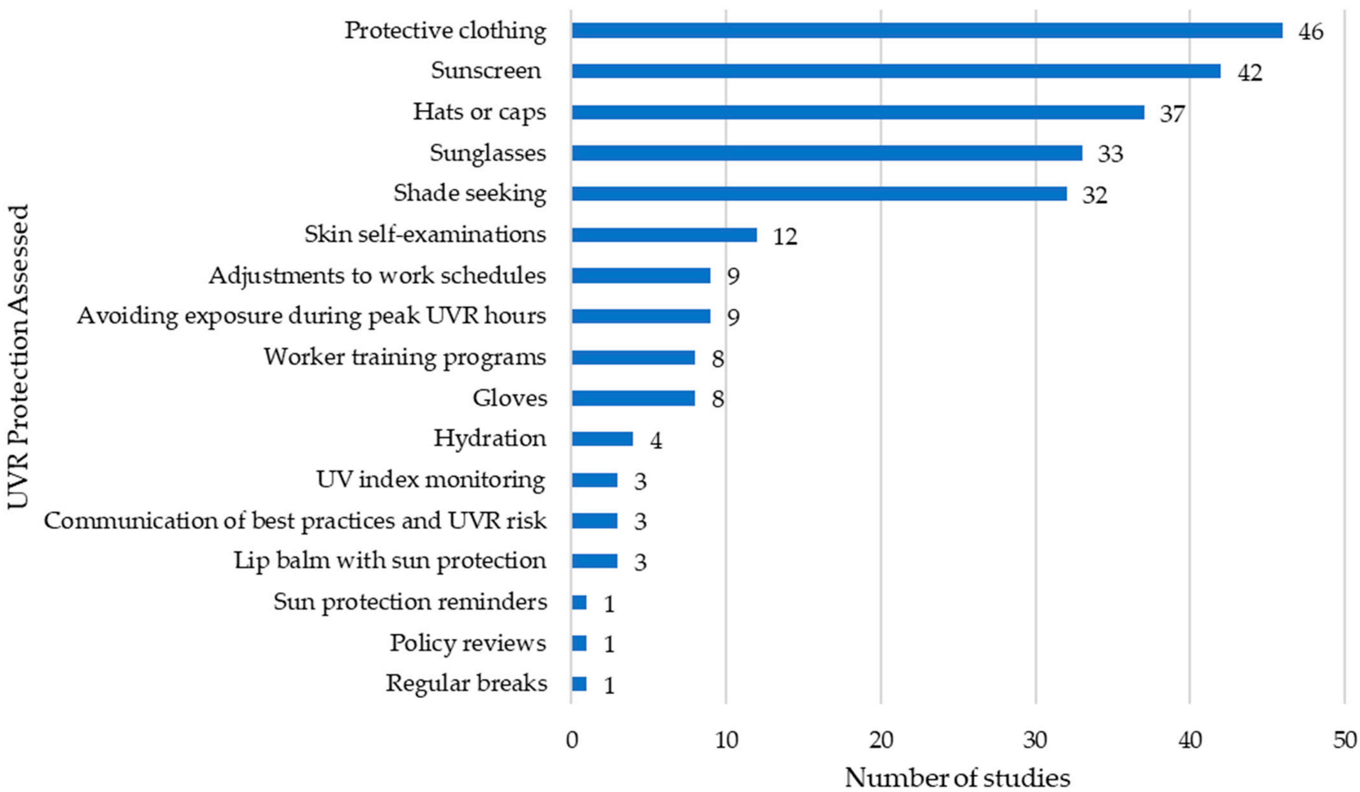

Figure 5. Frequency of UVR protection strategies assessed in the included studies.

The level of adherence to protective strategies was generally low to moderate, with particular emphasis on the limited use of sunscreen, sunglasses, and shade [22–25,27–29,31,32,34,38–42,44,46–48,51,53–59,62–65,68,70–73]. High adherence was observed only in contexts where structured interventions, continuous training, and direct institutional support were implemented [27,31,34,35,37–39,52,59–61,66].

The 52 included studies, [22–73] exhibited a heterogeneous geographical distribution, with most of the evidence originating from Europe and North America. European studies conducted in countries including Germany, Italy, the United Kingdom, Denmark, and Spain have consistently reported high cumulative occupational exposure to UVR, combined with inconsistent adoption of sun protection measures. Studies among construction and agricultural workers in the United Kingdom described low and irregular use of protective measures, particularly in the absence of structured workplace policies [22,35]. Similarly, Italian studies focusing on outdoor workers highlighted sustained exposure and insufficient preventive practices across occupational settings [40,54]. Evidence from Ger-many repeatedly demonstrated partial and inconsistent adoption of sun protection measures among outdoor workers, despite high exposure levels [38,60,71], while studies from Denmark and Spain reported comparable patterns, with limited translation of risk awareness into consistent protective behaviour [64,66].

North American studies, mainly from the United States and Canada, investigated a wide range of occupational groups, including agricultural workers, construction workers, postal workers and public sector employees, and consistently reported low to moderate adherence to sun protection measures in routine occupational settings [26,37,63,67]. Studies conducted outside Europe and North America, including Australia, China, Iran and Brazil, also reported limited use of sun protection among outdoor workers, suggesting that suboptimal occupational sun protection is a global issue across diverse climatic and cultural contexts [25,29,50,52].

Apparent differences were observed across occupational groups. Agricultural workers were among the most frequently studied populations and were consistently characterised by prolonged daily exposure to solar ultraviolet radiation across diverse geographical contexts [23,25,26,40,60,63,71]. Across multiple studies, the use of hats or protective clothing was reported more frequently than other measures, while sunscreen use remained irregular or absent [23,26,39,47]. Construction workers demonstrated heterogeneous patterns of protection, with several studies reporting low adherence to sun protection measures in the absence of formal workplace policies or training programmes [22,35]. Other occupational groups, including fishermen, municipal service workers and postal workers, were less frequently studied but often reported remarkably low uptake of sun protection measures, in some cases indicating minimal or no routine protective behaviour during work activities [29,31,44].

Studies involving outdoor workers in Germany, Switzerland, France, the United States and Australia demonstrated heterogeneous patterns in the adoption of sun protection measures. Across these settings, physical protective measures—such as wearing shirts with sleeves—were more consistently reported than behavioural measures, particularly sunscreen use [57,58,73]. However, the type of protection most adopted varied according to both occupational context and geographical location. For example, studies conducted in Germany reported the routine use of shirts with sleeves among outdoor workers. In contrast, studies involving Australian farmers more frequently described the use of hats and collared shirts [58,73].

Organisational measures, including training programmes, workplace policies, and communication-based interventions, were assessed in a smaller subset of studies but consistently showed positive effects on knowledge, risk perception, and adoption of sun protection measures when systematically implemented [37,42,51,59].

Table A2, in Appendix A, presents the studies grouped by professional category, detailing the exposure assessment method, type of protection evaluated, level of adherence (low, moderate, high, or not reported), and main findings. When data were unavailable, the review explicitly indicated this but retained the studies in the synthesis due to their contextual relevance.

Methodological heterogeneity, combined with the diversity of occupational contexts and objectives, justified the choice of a qualitative and thematic analysis. This review interprets the results based on the protection strategies adopted, the occupational context and the sociodemographic characteristics of the populations studied.

3.3. Risk of Bias in Studies

This review assessed the risk of bias for all 52 included studies [22–73], considering methodological domains relevant to their design, including reporting completeness, ethical procedures, sampling adequacy, outcome measurement validity, and analytical robustness. Although this review did not conduct a meta-analysis, it considered the potential for publication bias, recognising the possibility of underrepresentation of studies with negative findings or from lower-impact journals.

All studies, [22–73], clearly stated their objectives and provided complete bibliographic information. This review considered the study design appropriate in all cases. Potential sources of bias were identified, particularly due to the use of self-reported data and convenience sampling, which may introduce recall or social desirability bias [22,41,45,53,56,69,71,73].

All studies adequately described their sample characteristics. However, 30 studies [22–25,27–29,31,34,37–40,43,45,46,48,50,51,53,55,56,63,64,66,68,69,71–73] did not provide a formal statistical justification for the sample size, limiting statistical power and external validity. Ethical approval or informed consent procedures were reported in 46 studies [22–25,27,28,30–38,40,42–44,46–55,57–70,72,73], ensuring compliance with research ethics standards across most included articles. Six studies [26,29,39,45,56,71] did not mention any ethical procedures, which constitutes a notable methodological weakness.

All studies clearly defined their outcomes. In 44 studies [22–30,32,33,35–38,40–45,47–50,52–55,57–62,64–67,69,70,72,73], the measurement tools employed were either validated or demonstrated reliability. In contrast, eight studies [29,38,39,46,51,56,63,68] used instruments that lacked formal validation or reported limited internal consistency.

In terms of statistical analysis, 40 studies [22–25,27–33,35–38,40,42–44,46–50,52,54,55,57–70,72,73] employed appropriate inferential methods, including regression models, ANOVA, and non-parametric tests. The remaining seven studies [26,34,41,45,51,53,71] relied exclusively on descriptive statistics, which restricts the analytical depth.

Clinical or public health relevance was discussed in 49 studies [22,24–33,35–40,42–48,50,52–55,57–70,72,73], most of which highlighted the need for structural and behavioural interventions to reduce solar UV radiation exposure in outdoor occupations. The remaining four studies [23,41,49,71] did not discuss the practical implications of their findings. Among the 17 longitudinal or interventional studies [22,25,27,30,35,36,43,44,47,54,57,60–62,66,67,70], the authors reported and justified losses to follow-up when relevant. Appendix A—Table A3 provides a detailed summary of the individual risk of bias assessments for each study.

The main limitations identified include the predominance of self-reported data, the lack of formal justification for sample size, the use of non-validated measurement tools, and the restriction of many analyses to descriptive data. Furthermore, considerable methodological heterogeneity was observed across studies, hindering direct comparison of results and precluding the performance of a meta-analysis. These limitations compromise the generalisability of the findings, requiring a cautious interpretation of the available evidence.

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4. Discussion

Considering the studies included in this review, methodological heterogeneity was observed, particularly in study design, data collection instruments, effectiveness criteria, and the protective strategies assessed. While this methodological diversity poses limitations for quantitative comparisons, it enriches the qualitative synthesis and enables a comprehensive understanding of protective practices across varied occupational contexts.

The categorisation of protective strategies into three domains—physical, behavioural, and organisational—proved useful in elucidating the contextual factors influencing their adoption and effectiveness. The evidence highlights a misalignment between awareness of the risks associated with solar UVR exposure and the practical implementation of protective measures, underscoring the need for more effective prevention policies. This gap is especially concerning given the growing recognition of solar UVR as an occupational carcinogen by the International Agency for Research on Cancer (IARC), with chronic exposure posing a serious threat to workers' health [6,33].

4.1. Health Effects and the Importance of Protection

The studies included in this review consistently confirm the adverse health effects of occupational exposure to solar ultraviolet radiation, with particular emphasis on dermatological, ocular, and photoageing-related outcomes. Non-melanoma skin cancers, including basal cell carcinoma and squamous cell carcinoma, were the most frequently re-ported conditions, especially among agricultural and construction workers, although they were also observed across other outdoor occupational groups [40]. These findings are in line with previous research indicating that most occupational UVR exposures exceed the thresholds recommended by organisations such as the American Conference of Governmental Industrial Hygienists (ACGIH) [32,40]. Evidence suggests that malignant melanoma appears to be less frequent among outdoor workers compared with indoor workers experiencing intermittent intense exposure, whereas non-melanoma skin cancers remain the primary occupational concern [54]. The use of shade, either through natural or artificial means, or performing work tasks in shaded areas, emerges as an effective strategy to reduce the risk of UVR-induced dermatological diseases [74]. Working in the shade involves working in shaded areas, taking breaks in the shade, or even using structures such as tarpaulins or awnings. Its availability and use vary significantly across different occupations and workplaces [25,40,53,72]. A study of German outdoor workers found that 56.0% frequently or always received a shaded seat during working hours, and 64.8% had a shaded spot for breaks [72]. In another study, involving German outdoor workers, 23.7% of participants had the opportunity to work in a shaded area [53].

Another significant consequence of UVR exposure is ocular damage, including pterygium, cataracts, and macular degeneration [75,76]. The use of sunglasses remains one of the most effective preventive measures for UVR-related eye conditions, but its use is not consistently high across all risk groups [25,34,38,73,77]. However, their effectiveness depends on several factors, such as lens size, frame design, and specific UV protection standards [78]. Targeted training initiatives should promote the uptake of sunglasses among outdoor workers by raising awareness about the risks of solar UVR exposure and the importance of eye protection as a preventive strategy [79]. In a study conducted in Germany, approximately 31% of outdoor workers reported using sunglasses "always" or "frequently" during work activities [38]. Similar findings were observed in a study of golf course maintenance workers in Ireland, in which 58% reported wearing sunglasses at work [34]. Gender differences were also identified, with female outdoor workers in Germany tending to use sunglasses more frequently than their male counterparts, suggesting distinct behavioural patterns in the adoption of ocular protection [38]. Occupational differences were likewise documented. For example, research conducted in Queensland, Australia, revealed that nearly half of outdoor workers used wraparound sunglasses, which provide high levels of protection against ultraviolet radiation [25]. In contrast, in the Irish study, although 58% of workers reported wearing sunglasses, usage was significantly higher among younger workers and those in supervisory positions [34]. Furthermore, evidence suggests that the provision of sunglasses by employers represents a key factor in increasing adherence to this type of protection, reinforcing the importance of organisational measures in promoting ocular protection in occupational settings [34].

Several studies [40,50] reported the cumulative effects of UVR on skin photoaging, including loss of elasticity, hyperpigmentation, and premature wrinkling, particularly among professions characterised by prolonged sun exposure over many years. Although many perceive photoaging primarily as an aesthetic concern, it also reflects structural alterations in the skin associated with cellular mutations and potential carcinogenesis. Preventing such effects requires a combined approach that integrates physical and behavioural protective strategies, which occupational settings often fail to implement consistently [74,80]. Moreover, broader environmental and lifestyle factors, such as air pollution and smoking, also influence skin ageing. This highlights the need for comprehensive prevention strategies that address multiple risk determinants rather than focusing exclusively on occupational UVR exposure [81]. The use of sunscreen is widely recognised as an effective measure for reducing the risk of skin cancer as well as for preventing photoaging [51]. However, the studies included in this review indicate limited adherence to this protective measure in occupational settings. In Germany, only 35.6% of outdoor workers re-ported using sunscreen on their faces, and 29.6% on other parts of their bodies [73]. Similarly, in the United States, a study involving state park workers found that 52.3% of participants never or rarely used sunscreen during work activities [42].

The use of protective clothing and hats or helmets is considered an effective preventive measure against occupational exposure to solar ultraviolet radiation [57,58]. A study among rural Australian farmers found that, although the majority rated the use of wide-brimmed hats (89.6%), collared shirts (89.5%) and long-sleeved shirts (82.3%) as "very" or "extremely important", the proportion of workers who reported "always" adopting these behaviours was substantially lower, at 33.9%, 44.8% and 29.6%, respectively [58]. In contrast, among agricultural and construction workers in the United States, protective clothing was identified as the most prevalent sun-safe behaviour. Agricultural workers demonstrated a higher prevalence of protective clothing use compared with national estimates for wide-brimmed hats, long-sleeved shirts and long trousers [57].

It is also important to recognise that the health risks associated with solar UVR exposure are not constant throughout the year and depend on contextual factors such as geographical location, latitude, seasonality, and individual skin phototype [40,48]. Consequently, outdoor workers chronically exposed to solar UVR may experience fewer acute sunburn episodes [82]. In addition, some workers may preferentially choose outdoor occupations because they enjoy working outdoors or value tanned skin, which may further reinforce a perception of lower personal risk and the use of sunscreen [83,84].

4.2. Measures of Protection: Adherence and Effectiveness

The categorisation of protective methods revealed distinct patterns of adherence and effectiveness among workers, as detailed in Table A2 (Appendix A). Physical measures, such as the use of wide-brimmed hats, long-sleeved clothing, and UV-protective fabrics, demonstrated high effectiveness in directly reducing UVR exposure [25,26,48].

Multiple contextual and occupational factors frequently hinder outdoor workers' adherence to sun protection measures. Thermal discomfort that arises from wearing protective clothing in high-temperature environments often discourages workers from using such equipment [74]. A study conducted in Denmark found that wearing long pants and long shirts was perceived as either too hot or disruptive in the workplace [64]. Furthermore, many workers perceive that specific protective measures—such as sunscreen use or specialised clothing—reduce work productivity, which significantly deters their adoption [85]—the lack of mandatory occupational regulations specifically addressing protection against solar UVR further compounds these challenges. Without binding legal standards, workers often feel less motivated to adopt preventive behaviours consistently [73].

Behavioural measures, particularly sunscreen application, were the most frequently reported but also showed the lowest levels of adherence [23,25,29,32,39,40,42,45–48,54,56–58,62–65,68,70–72]. Several factors contribute to this trend: the lack of routine reapplication during the working day, the belief that sunscreen is unnecessary on cloudy days, the unavailability of free sunscreen provided by employers, and an overall undervaluation of UVR risks by workers [64,73,86,87]. In a study of Danish workers, access to sun protection measures, such as shade (5.3%), sunscreen (29.6%), and information (11.6%), was limited by employers [64]. A study with Spanish lifeguards indicates that sunscreen reapplication rates are low: 55.2% applied it in the morning, only 30.1% reapplied between 1 p.m. and 2 p.m., and 20.7% between 3 p.m. and 4 p.m. [66]. In another study with US naval aviation workers, only 12.3% of respondents reported frequently using sunscreen at work, compared to 36.5% who reported regular use during outdoor leisure activities, suggesting a barrier to workplace use [41]. Another study in Iran reports that only half of construction workers and 55% of farmers reported applying sunscreen only once a day [33]. The same study also states that 82% of agricultural workers and 40% of construction workers agreed with the incorrect statement that 'Sunscreen is not necessary on a cloudy/overcast day' [33]. In agricultural settings, factors such as dust, dirt, and excessive perspiration can make applying sunscreen impractical [39]. The use of sunscreens with inadequate sun protection factor (SPF) or the application of insufficient quantities are technical shortcomings that further compromise the measure's effectiveness [88].

Organisational measures, though less frequently evaluated, demonstrated considerable preventive potential. Adjusting work schedules to avoid periods of peak UV intensity, providing shade in outdoor work environments, and implementing regular breaks are effective strategies for reducing exposure to UVR. However, they remain underutilised due to the logistical and structural demands placed on employers [45,72,74,80]. Approximately 9.3% of managers in a US study reported that the UV Index was monitored to ad-just work schedules [45]. The absence of a safety culture and dedicated solar UV protection policies within companies may also undermine the implementation and impact of such measures. Additionally, countries with specific labour legislation and regular workplace inspections, such as Australia and Germany, tend to show higher effectiveness in the ap-plication of sun protection strategies [25,49,89].

4.3. Synthesis of Occupational Groups and Impact

The analysis of the included studies revealed that the most represented professions were agriculture and construction, reflecting the inherently high levels of solar exposure associated with these activities [22,23,25,30,32,33,35,36,39,46,47,57,58,68,69]. However, other relevant occupations—such as gardening, urban sanitation, fishing, maintenance, and lifeguarding—were underrepresented, which may indicate a research gap and a degree of risk invisibility in specific sectors [24,27–29,34,50,65]. This uneven distribution limits the generalisability of the findings and highlights the need for more diverse and inclusive research across occupational groups.

This review also observed that adherence to protective strategies varies significantly between professional groups, even when levels of UVR exposure are similar. Differences in cultural norms, resource availability, health literacy, and attitudes toward sun exposure may explain this variation. For instance, in specific cultural contexts, sun exposure is perceived as a symbol of health or masculinity, which can diminish the acceptance of protective clothing or wide-brimmed hats [87]. Studies conducted in rural agricultural settings in the United States indicate that inconsistent sun protection is strongly influenced by the normalisation of occupational solar exposure, traditional masculine work norms and a culture of self-reliance, in which prevention is perceived as an individual rather than organisational responsibility, favouring physical protection over sunscreen use [40]. In contrast, research involving young Latino day labourers highlight additional culturally mediated barriers, including the aesthetic value attributed to tanning, gender-related perceptions of sun protection, limited health literacy and social vulnerability associated with precarious employment and migration status [63]. In these contexts, sun protection tends to be deprioritised in favour of immediate work demands, and the absence of role modelling by supervisors or peers further reduces adoption [40,63]. Level of education is a factor that influences adherence to sunscreen application. One study found that Hispanic outdoor workers with some college education were more likely to use sunscreen than those with a high school education or less [64].

Evidence indicates that the presence of continuous occupational health training programmes is positively associated with the adoption of preventive behaviours. Organisations that implement regular educational campaigns, grounded in scientific evidence and tailored to the characteristics of their workforce, tend to achieve better outcomes in terms of sun protection. This underscores the central role of training as a key component of effective prevention [74]. A study of Danish outdoor workers found that, following a multi-component intervention, the use of sunscreen at work increased significantly. The percentage of workers who used it 'often/always' rose from 37% in 2016/17 to 52% in 2020 [43].

4.4. Measurement Instruments and Emerging Monitoring Technologies

Accurate assessment of occupational exposure to solar ultraviolet radiation remains a significant challenge in both research and preventive practice. Most studies included in this review relied on self-reported exposure, proxy indicators such as time spent outdoors, or environmental metrics including the UV Index, which may not adequately reflect individual cumulative dose or anatomical exposure variability. Several authors highlighted that such approaches limit the precision of exposure–response assessments and the evaluation of protective measures [39,40,60,73].

Direct measurement using radiometers, spectroradiometers, or personal dosimeters provides more reliable estimates of UVR exposure. However, these instruments are often costly, fragile, and impractical for routine occupational monitoring. Technical constraints related to calibration, spectral weighting, body positioning, and environmental variability further complicate the large-scale implementation of these methods in occupational settings [90,91].

Recent advances in intelligent monitoring technologies, including wearable sensors and smartphone-based systems, have been proposed as promising tools to bridge the gap between scientific accuracy and real-world applicability. These systems aim to provide real-time feedback on UVR exposure and support adaptive preventive behaviours; nevertheless, current evidence indicates that their accuracy, robustness, and validation under diverse occupational conditions remain limited, requiring further development and standardisation before widespread adoption [92,93].

4.5. Limitations and Future Research

Some of the studies included in this review relied on self-reported data collected through questionnaires that lacked formal validation, raising concerns regarding the reliability of the information obtained [42,73]. Furthermore, excessively lengthy questionnaires may negatively affect response quality and completeness [61]. The absence of a standardised method for UVR exposure assessment, along with the lack of dedicated legislation, hinders cross-study comparisons and prevents the development of robust quantitative syntheses [94]. The free provision of personal protective equipment (PPE), training, and educational initiatives, along with the restructuring of work schedules, are essential measures to ensure safer working environments [89].

Additionally, this systematic review included only studies published in English and retrieved from three specific databases. This limitation may have narrowed the scope of the analysis. Moreover, the wide range of occupational groups analysed reduced the feasibility of direct comparisons between studies. The application of exclusion criteria resulted in this review excluding certain studies with potentially relevant findings. To address this, the review employed a snowballing technique to enhance coverage [19].

Further research is needed to assess, in the long term, the effectiveness of various protective methods and to identify the specific characteristics required for their success [23,60]. This review recommends studies that employ biomarkers to evaluate internal UV doses and the effectiveness of sun protection measures, as such studies may help identify the most effective strategies for each scenario [95]. It also emphasises the importance of investigations assessing workers' knowledge and the practical application of protective measures to gain a broader understanding of their needs. Researchers should conduct these investigations using validated instruments [96].

5. Conclusions

Occupational exposure to solar UVR constitutes a widely recognised health risk for outdoor workers, significantly contributing to the increased incidence of skin cancers, ocular damage, premature photoaging, and other adverse health effects. This systematic review revealed that, despite the existence of numerous protective strategies—physical, behavioural, and organisational—their implementation in real-world settings remains limited, heterogeneous, and frequently inadequate.

Physical protective measures, such as appropriate clothing and wide-brimmed hats, demonstrated proven effectiveness, particularly when provided and actively promoted by employers. Behavioural strategies, especially sunscreen application, exhibited variable and often insufficient adherence, underscoring the need for educational interventions and attitude change. Although less extensively studied, organisational measures emerged as promising risk management tools, notably through schedule adjustments and the provision of shaded work areas.

The methodological limitations identified in the available evidence—including the predominance of descriptive studies, non-validated instruments, and the absence of longitudinal data—highlight the urgent need for more robust, multidisciplinary research focused on objective outcomes. Furthermore, the underrepresentation of certain occupational groups and the lack of standardised exposure assessment methods hinder the development of generalisable recommendations.

In this context, the present review contributes to managing occupational exposure to solar UVR by offering a comprehensive synthesis of the protective strategies employed, their adherence levels, and the practical constraints observed. The findings reinforce the need for more assertive public policies that integrate solar UVR into the legal framework of occupational hazards, establish exposure limits, and actively promote healthy work environments.

Adequate protection of outdoor workers requires an integrated approach, grounded in scientific evidence, institutional commitment, and cultural change. Only through the combination of these dimensions will it be possible to mitigate the risks associated with solar exposure and ensure dignified, safe, and equitable working conditions for all professionals exposed to it.

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Appendix A

Table A1. Keywords used in database searches.

Databases	Adapted Query and Database Filters
Scopus	(TITLE-ABS-KEY (“outdoor”) OR TITLE-ABS-KEY (“work*”) OR TITLE-ABS-KEY (“occupational”) OR TITLE-ABS-KEY (“workplace”) AND TITLE-ABS-KEY (“ultraviolet radiation”) OR TITLE-ABS-KEY (“uv radiation”) OR TITLE-ABS-KEY (“uvr”) AND TITLE-ABS-KEY (“protection”) OR TITLE-ABS-KEY (“preventive”) OR TITLE-ABS-KEY (“ppe”)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”))
	(TITLE-ABS-KEY (“outdoor”) OR TITLE-ABS-KEY (“work*”) OR TITLE-ABS-KEY (“occupational”) OR TITLE-ABS-KEY (“workplace”) AND TITLE-ABS-KEY (“ultraviolet radiation”) OR TITLE-ABS-KEY (“solar radiation”) OR TITLE-ABS-KEY (“sun exposure”) AND TITLE-ABS-KEY (“protect*”) OR TITLE-ABS-KEY (“PPE”) OR TITLE-ABS-KEY (“sunscreen”) OR TITLE-ABS-KEY (“protective”) OR TITLE-ABS-KEY (“control measures”)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”))
	(TITLE-ABS-KEY (“outdoor”) OR TITLE-ABS-KEY (“work*”) OR TITLE-ABS-KEY (“occupational“) AND TITLE-ABS-KEY (“solar ultraviolet radiation”) OR TITLE-ABS-KEY (“solar UV”) OR TITLE-ABS-KEY (“ultraviolet radiation”) AND TITLE-ABS-KEY (“skin cancer”) OR TITLE-ABS-KEY (“cancer prevention”) OR TITLE-ABS-KEY (“primary prevention”)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”))
Web of Science	(TS = (“outdoor”) OR TS = (“work*”) OR TS = (“Occupational”) OR TS = (“Workplace”)) AND (TS = (“ultraviolet radiation”) OR TS = (“uv radiation”) OR TS = (“uvr”)) AND (TS = (“protection”) OR TS = (“preventive“) OR TS = (ppe)) and 2025 or 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 (Publication Years) and Article (Document Types) and English (Languages)
	(TS = (“outdoor”) OR TS = (“work*”) OR TS = (“occupational”) OR TS = (“workplace”)) AND (TS = (“ultraviolet radiation”) OR TS = (“solar radiation”) OR TS = (“sun exposure”)) AND (TS = (“protect*”) OR

	TS = (PPE) OR TS = ("sunscreen") OR TS = ("protective") OR TS = ("control measures")) and 2025 or 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2016 or 2017 or 2015 (Publication Years) and Article (Document Types) and English (Languages)
	(TS = ("outdoor") OR TS = (" work*") OR TS = ("occupational ")) AND (TS = ("solar ultraviolet radiation") OR TS = ("solar UV") OR TS = ("ultraviolet radiation")) AND (TS = ("skin cancer") OR TS = ("cancer prevention") OR TS = ("primary prevention")) and 2025 or 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 (Publication Years) and Article (Document Types) and English (Languages)
PubMed	(("outdoor" [All Fields] OR "work*" [All Fields] OR "Occupational" [All Fields] OR "Workplace" [All Fields]) AND ("ultraviolet radiation" [All Fields] OR "uv radiation" [All Fields] OR "uvr" [All Fields]) AND ("protection" [All Fields] OR "preventive" [All Fields] OR ("polit philos econ" [Journal] OR "ppe" [All Fields]))) AND ((y_10 [Filter]) AND (humans [Filter]) AND (English [Filter]))
	(("outdoor" [All Fields] OR "work*" [All Fields] OR "occupational" [All Fields] OR "workplace" [All Fields]) AND ("ultraviolet radiation" [All Fields] OR "solar radiation" [All Fields] OR "sun exposure" [All Fields]) AND ("protect*" [All Fields] OR "PPE" [All Fields] OR "sunscreen" [All Fields] OR "protective" [All Fields] OR "control measures" [All Fields])) AND ((y_10 [Filter]) AND (humans [Filter]) AND (English [Filter]))
	(("outdoor" [All Fields] OR "work*" [All Fields] OR "occupational" [All Fields]) AND ("solar ultraviolet radiation" [All Fields] OR "solar UV" [All Fields] OR "ultraviolet radiation" [All Fields]) AND ("skin cancer" [All Fields] OR "cancer prevention" [All Fields] OR "primary prevention" [All Fields])) AND ((y_10 [Filter]) AND (humans [Filter]) AND (English [Filter]))

Table A2. Characteristics of studies grouped by professions and UVR protection methods.

Profession/Professional Groups	UVR Measurement Methods	UVR Protection Assessed	Adherence to UVR Protection Measures	Study Reference	Main Results
Farmers	Questionnaire	Cap	Low	[58]	- Limited access to shade [47]; - Low adherence to photoprotection measures [58]; - Perception of present risk, but not always translated into preventive behaviour [30,32,58]; - Inadequate protection in general [36]; - Sun protection behaviours associated with socio-demographic factors (age, gender, education and type of work) [30,36]; - Need for training actions [36,68]; - Use of sunscreen associated with a higher risk of burning [68]; - Protection motivated by occupational factors rather than by knowledge about solar risks [23];
		Hat	High	[32,46,68]	
			Low	[58]	
			Moderate	[30,39]	
			Not reported	[36,47]	
		Avoid sun exposure	Not reported	[36]	
		Avoid sun exposure at peak hours	Low	[32]	
			Moderate	[30]	
		Gloves	Low	[58]	
		Sunglasses	High	[39]	
			Low	[47,58,68]	
			Moderate	[30,32]	
		Sunscreen	Low	[32,39,46,47,58,68]	
			Moderate	[30]	
			Not reported	[36]	
		Shadow	Low	[32,39,46,47,68]	
			Moderate	[30]	
		Protective clothing	High	[46,47]	
			Low	[39,58,68]	
			Moderate	[32]	
	Questionnaire Direct observation Solar Protection Score (SPS) Calculation	Hat	Low	[23]	
		Gloves	Not reported		
		Sunglasses	Low		
		Sunscreen	Low		
		Shadow	Not reported		
		Protective clothing	High		
	Questionnaire Direct observation	Wide-brimmed hat	Low	[69]	
		Exposure risk communication	Low		

	Clinical interview Photo tracking	Gloves	Low		
		Sunscreen	Moderate		
		Skin self-surveillance	Low		
		Protective clothing	Low		
Farmers Construction Gardeners Other occupational groups	Questionnaire	Sunscreen	Moderate	[73]	- One third of outdoor workers reported using five key sun protection measures "frequently" or "always" [73]; - Women used sunscreen and sunglasses more often than men [73].
		Sunglasses	Moderate		
		Shadow	Moderate		
		Hat	Moderate		
		Protective clothing	High		
Farmers Construction	Questionnaire	Hat	Not reported	[57]	- Low practical application of training actions [33]; - Barriers to the use of PPE and sunscreen more frequent in construction workers [33]; - Superior knowledge and attitudes in civil construction, but with greater barriers [33]; - Farmers showed less knowledge, but better perception of the usefulness of the training received [33].
		Worker training	Low	[33]	
		UV index monitoring	Low	[33]	
		Sunscreen	Low	[57]	
			Moderate	[33]	
		Shadow	Low	[57]	
		Protective clothing	High	[57]	
			Moderate	[33]	
Farmers Gardeners Mountain guides	Questionnaire Dermatological examination	Hat	Low	[60]	- High risk of NMSC in outdoor professions [60]; - Marked differences between professions [60].
		Sunscreen	High		
		Skin cancer screening	Low		
		Protective clothing	Low		
Farmers Roofers Gardeners	Questionnaire	Avoid sun exposure at peak hours	Not reported	[71]	- Risk perception positively influences protective behaviors [71].
		Sunglasses	Not reported		
		Sunscreen	Low		
		Protective clothing	Not reported		
Postmen	Questionnaire	Hydration	Low	[31]	- Sun protection behaviors associated with sociodemographic factors (sex, age, skin type, and function) [31]; - Training not correlated with best sun protection practice [31]; - Necessary organizational policies [31].
		UV index monitoring	High		
		Sunglasses	Low		
		Sunscreen	High		
		Shadow	High		
		Protective clothing	High		
		Hat	Moderate	[25]	

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	Questionnaire Direct observation	Sunglasses	Moderate		
		Protective clothing	Not reported		
Construction	Dosimetry Questionnaire Skin type assessment	Hat	Low	[25]	- Use of scarce and disorganized PPE [25]; - Shadow little available and poorly used [25]; - Positive behavior changes in 9 out of 10 measures [35]; - Little change in knowledge [35]; - Organizational policies defined as effective strategy [22].
		Sunglasses	Low		
		Sunscreen	Low		
		Shadow	Low		
		Protective clothing	Low		
	Questionnaire	Skin self-surveillance	High	[35]	
			Moderate	[22]	
		Protective helmet	Low	[35]	
		Hat	Low	[22]	
		Avoid sun exposure at peak hours	Moderate	[35]	
			Low	[22]	
		Hydration	High	[22,35]	
		UV index monitoring	Low	[22,35]	
		Sunglasses	High	[35]	
			Moderate	[22]	
		Sunscreen	High	[35]	
			Moderate	[22]	
		Task rotation	Moderate	[35]	
			Low	[22]	
		Shadow	Moderate	[35]	
			Low	[22]	
		Protective clothing	Moderate	[22,35]	
Mountain guides	Questionnaire	Skin self-surveillance	Moderate	[61]	- High exposure to UVR [61].
		Sunscreen	High		
		Skin cancer screening	Moderate		
Sailors	Questionnaire	Skin self-surveillance	Moderate	[52]	- Intervention via SMS was effective: significant increase in preventive behaviors and motivation for protection [52].
		Hat	Moderate		
		Avoid sun exposure at peak hours	Moderate		
		Gloves	Low		
		Sunglasses	Moderate		

		Sunscreen	High		
		Skin cancer screening	Low		
		Shadow	Moderate		
		Protective clothing	Moderate		
Military aviation	Questionnaire	Reminders for using sun protection	Low	[41]	- Protection more frequently outside work than in the workplace [41].
		Sunscreen	Moderate		
		Shadow	Low		
		Protective clothing	Moderate		
Navy Military	Questionnaire	Sunscreen	Low	[70]	- Advanced age, outdoor occupation, and fair skin increase the risk of actinic keratosis [70].
	Complete dermatological examination performed by experts	Skin cancer screening	Low		
Lifeguards	Questionnaire Personal dosimetry	Hat	Low	[66]	- High knowledge of sun protection; 96.3% recognized UV light as a cause of skin cancer [66]; - Need for effective sun protection measures [66].
		Avoid sun exposure at peak hours	Low		
		Sunglasses	High		
		Sunscreen	High		
		Shadow	Moderate		
		Protective clothing	Low		
Fishermen	Questionnaire	Sunscreen	Low	[29]	- 82.5% of fishermen have never used any sun protection measures [29]; - Lack of knowledge of appropriate measures [29]; - Urgent need for training [29].
Sanitation maintenance technicians	Questionnaire Dermatological examination	Skin self-surveillance	Low	[65]	- Need for more preventive measures [65].
		Sunscreen	Low		
		Skin cancer screening	Moderate		
Outdoor workers	Dosimetry	Hat	Low	[48]	- Protections were not used consistently [40,48,62]; - Intervention increased protection measures [59,67]; - Average cost/action was acceptable compared to other occupational health programs [67]; - Personalized messages (occupational or individual) increased intentions for sun protection [55]; - Face-to-face intervention significantly increased training
		Sunglasses		[48]	
		Sunscreen		[48]	
		Reduction of sun exposure time	Moderate	[49]	
		Shadow	Low	[48]	
		Shadow	Moderate	[49]	

	Protective clothing	Low	[48]	and communication [51]; - Shade in place associated with lower risk of sunburn [53]; - 69% reported never or rarely using sunscreen [38,54,63]; - Women and individuals with higher education used it more [63]; - Low availability and knowledge on the subject limit the use of protection [63,72]; - Need for more training and protection policies [40,54,62]; - Sun protection at work is used less often than for leisure or holidays in the sun [64]; - Lower prevalence of sunburn after intervention [37]; - Risk awareness increased after the intervention [72].
	Protective clothing	Moderate	[49]	
Questionnaire	Adjustment of working hours	Low	[51,62,64,67,72]	
		Moderate	[37]	
	Exposure risk assessment	Moderate	[67]	
		Low	[51]	
	Hat	Low	[38,53,64]	
		Moderate	[37,40,55,62,67,72]	
	Availability of PPE	Low	[51]	
	Worker training	Moderate	[51]	
		Low	[53,72]	
		Low		
	Gloves	Low	[38,62]	
	UV index monitoring	Low	[38,67]	
	Sunglasses	High	[37]	
		Low	[38,40,53,62]	
		Moderate	[47,67]	
	Breaks at work	High	[53]	
	Face shield	Low	[62]	
	Lip balm	Moderate	[37]	
	Sunscreen	Moderate	[51,55,67]	
		Low	[40,53,54,62–64,72]	
		Moderate	[37,38]	
	Skin cancer screening	Moderate	[67]	
		Low	[51]	
	Reduction of working time (overtime)	High	[72]	
	Review and monitoring of sun protection policies	Moderate	[67]	
	Shadow	High	[38]	
		Low	[40,51,53,55,72]	
		Moderate	[37,67,72]	
	Protective clothing	High	[38]	

			Low	[40,53,62]	
			Moderate	[37,51,55,64,67,72]	
	Questionnaire Direct observation	Hat	Low	[59]	
		Communicating Protective Practices	High		
		Worker training	High		
		Reminders for using sun protection	Moderate		
		Organizational protection measures	High		
		Sunglasses	Low		
		Sunscreen	High		
		Shadow	Moderate		
		Protective clothing	Moderate		
	Questionnaire Dosimetry Skin examination	Adjustment of working hours	Low	[43]	
		Hat	Moderate		
		Sunscreen	Moderate		
		Protective clothing	Moderate		
Maintenance workers (golf course)	Questionnaire	Hat	High	[34]	- Use of sun protection was more common in younger workers and in senior positions [34]; - Knowledge correlated with the use of protection [34]; - Scarce training [34]; - Need for organizational strategies and provision of PPE [34].
		Worker training	Low		
		Hydration	High		
		Sunglasses	Moderate		
		Sunscreen	High		
		Shadow	Low		
		Protective clothing	Moderate		
Maintenance workers (ski resort)	Questionnaire	Self-surveillance	Moderate	[27]	- Reduction in the prevalence of sunburn, after interventions [24]; - Workers with access to communication strategies showed better protective behaviors [27]; - Need to maintain the intervention strategy to maintain positive effects [27].
		Hat	Moderate	[24,27]	
		Avoid sun exposure at peak hours	Low	[27]	
		Sunglasses	High	[27]	
			Moderate	[24]	
		Lip balm	Moderate	[24,27]	

		Sunscreen	Moderate	[24,27]	
		Shadow	Low	[24,27]	
		Protective clothing	Moderate	[27]	
	Direct observation	Hat	Moderate	[28]	
		Exposure risk communication	Moderate		
		Worker training	Low		
		Sunglasses	Low		
		Sunscreen	Moderation		
		Shadow	Moderate		
Park workers	Questionnaire	Hat	Low	[42]	- Need for training [42].
		Gloves	Low		
		Sunglasses	Moderate		
		Sunscreen	Low		
		Shadow	Moderate		
		Protective clothing	Moderate		
Municipal service workers Electrical technicians	Dosimetry	Hat Gloves Sunglasses Shadow Protective clothing	Low	[44]	- Need for urgent protection measures [44].
Forestry workers Outdoor workers	Questionnaire Skin examination	Adjustment of working hours	Low	[56]	- Natural shade (trees) considered insufficient [56]; - Need for additional protective measures [56].
		Hat	Moderate		
		Sunglasses	Low		
		Sunscreen	Low		
		Shadow	Low		
		Protective clothing	Moderate		
Carriers	Questionnaire	Skin self-surveillance	Low	[45]	- Only a minority have protection and training policies [45].
		Exposure risk assessment	Low		
		Exposure risk communication	High		
		Availability of PPE	Moderate		

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		Worker training	Moderate		
		UV index monitoring	Low		
		Sunscreen	Low		
		Shadow	Low		
		Protective clothing	Moderate		
Street sweepers	Questionnaire Skin examination	Sunglasses	Moderate	[50]	- Young people used more protection than older people [50]; - Low prevalence of sun protection use [50].
		Sunscreen	Moderate		

Table A3. Methodological and risk of bias analysis of selected studies.

Study Reference	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
[22]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	N
[23]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	Y
[24]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[25]	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	NA
[26]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[27]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[28]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[29]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[30]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y
[31]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[32]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[33]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[34]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[35]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[36]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y
[37]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[38]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[39]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[40]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	Y
[41]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[42]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[43]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[44]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[45]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA
[46]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[47]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	Y
[48]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[49]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	NA
[50]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[51]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[52]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[53]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	NA
[54]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y
[55]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[56]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[57]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[58]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	NA
[59]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
[60]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[61]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	NA
[62]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[63]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	NA
[64]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	Y
[65]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	NA
[66]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	Y
[67]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
[68]	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	NA	Y	Y	Y	Y
[69]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y

[70]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	NA
[71]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	NA	Y	Y	Y	NA
[72]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NA	NA	Y	Y	Y	NA
[73]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	NA	Y	Y	Y

Y—Yes; N—No; NA—Not Applicable.

Quality assessment criteria	
Q1	Was the study purpose stated clearly?
Q2	Was relevant background literature reviewed?
Q3	Was the design appropriate for the research question?
Q4	Was the sample described in detail?
Q5	Was the sample size justified?
Q6	Was informed consent obtained?
Q7	Were the outcome measures reliable?
Q8	Were the outcome measures valid?
Q9	Was the method described in detail?
Q10	Were results reported in terms of statistical significance?
Q11	Were the analysis methods appropriate?
Q12	Was the importance of the practice reported?
Q13	Were any dropouts reported?
Q14	Were conclusions appropriate given the study methods?
Q15	Are there any implications for practice, given the results of the study?
Q16	Were limitations of the study acknowledged and described by the authors?

Figure A1. Questions from the Critical Review Form—Quantitative Studies [22].

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