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Perspective

Prevention of Occupational Skin Cancer Caused by Solar Ultraviolet Radiation Exposure: Recent Achievements and Perspectives

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Abstract: In fair-skinned populations worldwide, skin cancer is a serious public health threat. A significant percentage of all reported occupational diseases fall back on skin cancer. Over the past few decades, there has been a rise in the frequency of skin cancer diagnoses among outdoor workers. The main cause of non-melanoma skin cancer is solar ultraviolet radiation (UVR), which is also the most common occupational carcinogenic exposure in terms of the number of exposed workers (i.e., outdoor workers). Sun protection—and concomitantly the prevention of occupational skin cancer—is a component of workplace safety. The risks of solar UVR exposure at work are often disregarded in practice, despite the recent recognition of the need for measures to support outdoor workers' sun protection behavior. It is anticipated that occupational dermatology will become increasingly focused on sun safety in the coming decades. To handle current hurdles in a sustainable manner, the full range of preventive measures should be utilized. Existing strategies for the prevention of occupational skin cancer might be evolved and enriched by new (educational) concepts, methods, and/or technologies. In this, not only components of general prevention and individual prevention but also setting-based prevention and behavior-based prevention might be freshly thought through.

Keywords: actinic keratosis; basal cell carcinoma; melanoma; non-melanoma skin cancer; occupational; outdoor workers; prevention; skin cancer; solar ultraviolet radiation; squamous cell carcinoma; work-related

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Citation: Symanzik, C.; John, S.M. Prevention of Occupational Skin Cancer Caused by Solar Ultraviolet Radiation Exposure: Recent Achievements and Perspectives. *Dermato* **2024**, *4*, 46–59. https://doi.org/10.3390/dermato4020006

Academic Editor: Robert Gniadecki

Received: 1 March 2024
Revised: 21 March 2024
Accepted: 27 May 2024
Published: 6 June 2024

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1. Introduction

Occupational skin cancers account for a considerable share of all reported occupational diseases [1,2] and the proportion of individuals being diagnosed with skin cancer has increased over the previous decades [3,4]. Thus, skin cancer has grown to be a severe public health concern—especially affecting fair-skinned populations all over the world—with exposure to solar ultraviolet radiation (UVR) being the most important risk factor for these diseases [5]. As has been described in a World Health Organization (WHO) and International Labour Organization (ILO) systematic review, 1.6 billion people worldwide, which account for 28.4% of the working-age population, were exposed to UVR at work in 2019 [6]. Solar UVR, which is the most energetic part of the optical radiation, is classified into three categories: UV-A (wavelength [λ] = 315–400 nanometers [nm]), UV-B (λ = 280–315 nm), and UV-C (λ = 100–280 nm) [7]. UV-C does not reach the surface of the earth and is not relevant in daily sun protection, or rather solar UVR protection, practice. UV-B reaches the basal cell layer of the epidermis and relevantly contributes to the development of sunburns, deoxyribonucleic acid (DNA) damage, and skin cancers, whereas UV-A reaches even deeper, down to the subcutaneous fatty tissue, and mainly causes degradation of the collagen and elastin fibers of the dermis, which then leads to premature skin aging (photo-aging). Thus, in terms of the development of skin cancer, UV-B is of the utmost importance [8].

Oftentimes, malignant melanoma (MM) is in the focus of public attention in reports on skin cancer. Despite the fact that some current studies have suggested a possible link between chronic occupational sun damage and specific MM subtypes, such as lentigo maligna melanoma (LMM), the link between (cumulative) occupational solar UVR exposure and MM has been deemed inconclusive [9,10]. Intermittent UVR exposure, particularly in adolescents, as well as genetic predispositions, appear to play a more important role in the occurrence of MM [11]. Non-melanoma skin cancer (NMSC) is less likely to get a lot of public attention, but is way more relevant in terms of occupational skin cancer than MM. Current studies have shown that NMSC, more precisely described as keratinocyte carcinoma (KC) [12], manifesting as actinic keratosis (AK, intra-epidermal cutaneous squamous cell carcinoma (SCC)), invasive SCC, and/or basal cell carcinoma (BCC), is primarily caused by solar UVR [2,9,13–17]. It should be emphasized that NMSC is one of the few cancers that is treatable, easily detected, and, most importantly, completely preventable [1,18]. At the same time, particularly in long exposed outdoor workers, it is a highly chronic disease. As has been shown in the aforementioned review by Pega et al., for NMSC deaths, the population-attributable fractions (PAFs) were 29.0%, while for disability-adjusted life years (DALYs), they were 30.4%, and there were 0.5 million DALYs and 18,960 deaths related to NMSC [5]. The authors of the review thus stress that attributable deaths and DALYs nearly doubled between 2000 and 2019 [5].

Regarding the burden of NMSC, especially men and older age groups are identified as risk groups [5]. As a high-risk population for developing occupational skin cancer, the occupational group of outdoor workers (e.g., agriculture and forestry workers, market gardeners, sailors, and fishers, construction workers and craftsmen, like roofers, carpenters, brick layers, fitters, etc., as well as roadmen, pool attendants, mountain guides, etc.) has recently become a priority [1,19,20], as they are subjected to high levels of solar UVR since they spend the majority of their working hours outside [21]. As a result of this exposure, outdoor workers are at least twice as likely to develop KC than the average population, with SCC being most closely associated with *cumulative* solar UVR exposure [2,15,16,22]. In proportion to the number of workers exposed, solar UVR is by far the most important occupational carcinogenic exposure [23–25]. Regardless of the reality that millions of workers around the world are exposed to the occupational carcinogenic exposure represented by solar UVR for a significant portion of their working time, this work-related risk factor remains formally not recognized by directives and regulations regarding occupational safety and health in numerous parts of the globe [2,7,26]. Moreover, a precarious scenario is provoked by the fact that no universally accepted occupational exposure limit values are currently available, apart from a non-binding proposal by the International Commission on Non-Ionizing Radiation Protection (ICNIRP): an occupational UVR exposure limit equivalent to 1.0–1.3 Standard Erythema Doses (SED) per day; 1 SED equals 100 J/m^2 of the biologically weighted erythema action spectrum [26,27]. Against this background, this chapter focuses on recent achievements and perspectives for the prevention of occupational skin cancer.

2. Occupational Skin Cancer Prevention Strategies

2.1. Primary, Secondary, and Tertiary Prevention

Preventive measures can be subdivided into primary, secondary, and tertiary preventive measures [28,29], according to the point in time in which the measure is to be implemented. Generally, primary prevention takes place even before the illness manifests itself and aids in the avoidance of health-harming aspects with the goal of preventing disease onset in healthy individuals [30]. Secondary prevention seeks to keep diseases from progressing; it intervenes in existing risk scenarios, attempting to avoid them and mitigate the disease's repercussions [30]. Tertiary prevention focuses on restoring health whilst an illness has already manifested. In this, consequential harm of the illness is to be avoided, and recovery is to be made feasible [30]. Further, as displayed in Table 1, preventive measures can be characterized by the recipient (general prevention or individual prevention), as well as the contents or rather applied principle (behavior-based prevention or setting-based prevention).

Table 1. Classification of preventive measures according to recipient, content, and time of implementation. Adapted and modified from [30].

Recipient	Content/Principle	Time of Implementation
■ General prevention ■ Individual prevention	■ Setting-based prevention ■ Behavior-based prevention	■ Primary ■ Secondary ■ Tertiary

Regarding cancer, the International Agency for Research on Cancer (IARC) defines primary preventive measures as any preventive action that reduces the risk of developing cancer in humans [31], also differentiating measures carried out on the collective level and on the individual level [32], i.e., general prevention and individual prevention. It is crucial to point out that primary prevention should not be limited to the business sphere; instead, it might serve as part of a broader approach that includes preventative policies and initiatives at the institutional, governmental, and societal levels, as well as the adoption of norms, standards, and prevention-related efforts [18,32,33].

According to the IARC definition, secondary cancer prevention has two primary components: screening and early diagnosis, which will ultimately culminate in the early detection of precancerous conditions or malignancies in their early stages [31]. Occupational health surveillance of employees who are exposed to solar UVR and hence more prone to suffer from subsequent harmful effects is one of the most significant strategies of secondary prevention at work [18]. Workers with risk factors (e.g., fair skin phototypes I and II, using hydrochlorothiazide or immunosuppressants) should be treated with extra caution [18]. Periodic health assessments of workers by registered occupational health professionals are a common component of health surveillance [18], in which additional medical professionals—such as (occupational) dermatologists—should be consulted in supplemental health management if needed on an individual basis [7,10,33].

Tertiary prevention, as defined by the IARC, refers to strategies for intervention employed after disease consequences have already occurred [27]. Such efforts seek to provide a secure return to work, recovery from the disease, and a high quality of life in addition to compensation; they also involve medical and occupational rehabilitation of employees with UVR-related skin malignancies following treatment [27,33]. Recommended measures of primary, secondary, and tertiary occupational skin cancer prevention are listed in Table 2.

2.2. Technical, Organizational, and Person-Related (TOP) Measures

The quantity of solar UV exposure, the specific jobs to be performed in the sun, and the solar UV protection behaviors of the employees are relevant factors to consider regarding cumulative solar UVR exposure in outdoor workers; therefore, a large reduction in occupationally acquired UV doses for outdoor workers is required to avoid skin cancer caused by solar UV exposure [34]. Sun protection recommendations generally follow the so-called TOP principle (**t**echnical, **o**rganizational, and **p**erson-related measures in a hierarchical, ascending order) [35,36]. In contrast to the widely used preventive **S**TOP principle, **s**ubstitution of the hazardous agent is not feasible within the framework of the TOP principle for solar UVR prevention measures, as solar UVR cannot be substituted.

Table 2. Concrete actions in terms of primary, secondary, and tertiary prevention of occupational skin cancer. Adapted and modified from [4].

Primary Preventive Actions
• Introduction of a successful risk assessment process which has to be reviewed and updated frequently (e.g., medical examinations or even skin checks within the framework of occupational-medical health examinations) • Supply of informational materials (e.g., brochures, leaflets, mobile applications) • Health educational measures, such as health-pedagogical training (e.g., sun-safety trainings and skin cancer prevention trainings) • Arrangement of (scientifically sound) governmental campaigns and other projects (e.g., national or international campaign days for raising awareness) • Lawmakers collaborating to amend statutes regarding exposure to solar UVR
Secondary preventive actions
• Development and execution of health education interventions, such as encouraging self-examinations and seeking physician skin examinations, or teaching non-healthcare workers (e.g., hairdressers, cosmeticians/beauticians/aestheticians) in skin cancer identification • Working together with governments and the scientific community to organize and implement campaigns and other projects • Implementing standards and deciding which populations to screen • Establishing a framework for healthcare professionals to get continuous and updated training
Tertiary preventive actions
• Establishing standardized patient treatment algorithms • Establishing multidisciplinary cancer boards, which include not only physicians but also other health care professionals from various specialties (e.g., physicians specialized in oncology, surgery, radiology, pathology etc., clinical and research nurses, palliative care specialists, and social workers), in order to tackle the increasingly challenging tasks • Enhancing patient access to innovative medical treatments by collaborating with providers • Enhanced randomized controlled trial accessibility for patients

Abbreviations: UVR, ultraviolet radiation.

Measures according to a further step of the TOP principle should be implemented only when the preceding stage has been fully exhausted. Technical measures, which are the first measures to deploy, are utilized to avoid solar UVR exposure, e.g., by using different forms of shading, like sun sails or weather protection tents. Organizational measures, which follow technical measures, are deployed to avoid outdoor work at times of intensely shining sun, which is the case in Europe between April and September from around 11 a.m. to 4 p.m. [37]. Also, shifting working hours away from the noon heat might be beneficial to occupational safety (avoiding heat stroke). Working hours should be moved to the early mornings and later afternoon/evening, breaks should be taken in the shade, and individual job tasks should be completed in the shade, whenever possible. If technical and organizational measures are insufficient, person-related measures come into force. Workers should be provided with personal protective equipment (PPE), such as proper clothes (ideally long-sleeved shirts and long pants), protective brimmed headgear (i.e., broad-brimmed helmets or hats with sun shields, as well as ear and neck guards), and adequate sunglasses with wide, solar UVR-filtering lenses [31,32]. Although UVR protection factor (UPF) apparel is preferred, regular cotton T-shirts appear to provide adequate protection against solar UVR ('better a T-shirt than no shirt') [18]. Sunscreens must have a broad-spectrum filter (i.e., filter UV-A and UV-B rays), have a sun protection factor (SPF) of at least 30, but preferably 50+, and need to be water/sweat-resistant, as well as easily applicable so that they can be frequently re-applied throughout the day [18,31,32,38,39]. As has been depicted by Passeron et al., sufficient or rather the highest possible UV-B protection is especially relevant in fair-skinned individuals; humans with darker skin tend to be naturally better protected against UV-B and benefit from higher UV-A protection [8]. Despite this, widespread sayings, like 'black don't crack', which imply that persons with darker skin tones do not need protection against solar UVR, are plainly incorrect; also, persons with darker skin types need to protect their skin from solar UVR. All in all, choosing a sunscreen with the highest UV-B and UV-A protection would be ideal. It should be noted that sunscreens, however, should only be used when other methods of protection are ineffective or not deployable to the location (i.e., the face, as well as, in some cases, the back of the hands). It should always be kept in mind that sunscreens do not completely block UVR and should therefore be understood as a supplement to other UVR protection measures (e.g., textile sun protection). Figure 1 provides an overview of sun safety measures according to the TOP principle.

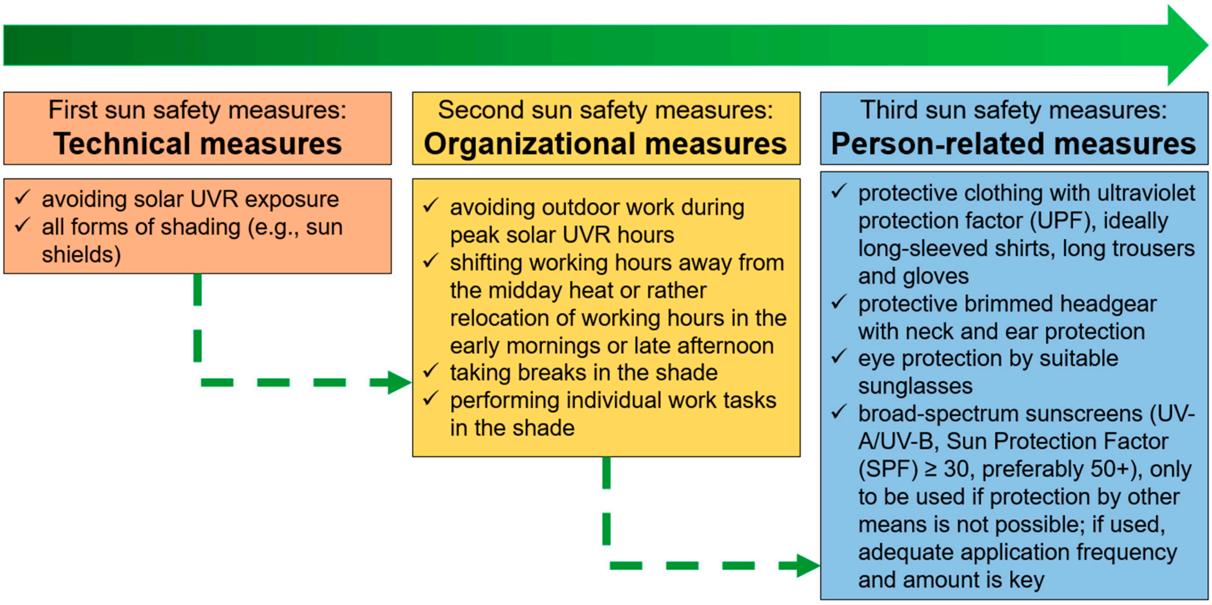

Figure 1. Sun safety measures according to the TOP principle (technical-, organizational-, and person-related). Adapted and modified from [40]. Abbreviations: UVR, ultraviolet radiation.

One example for a sun safety campaign is the popular Australian health campaign with the slogan 'Slip, Slop, Slap' launched by the Cancer Council in 1981 and updated in 2007 to 'Slip, Slop, Slap, Seek, Slide'. This campaign highlights the significance of sun safety measures to prevent sun damage and presents them in five easy steps [41]:

1. **Slip** on a long-sleeved shirt or sun protective clothing.
2. **Slop** on broad-spectrum sunscreen with a Sun Protection Factor (SPF) of 30 or greater and re-apply every two hours.
3. **Slap** on a hat, the wider the brim the better.
4. **Seek** shade or shelter during peak sun exposure times, generally from 10 a.m. to 4 p.m.
5. **Slide** on UV-protective sunglasses to protect the eyes.

Even though the campaign concentrates on the private field, it is aimed at the entire population, tackles key issues that are equally crucial for workplace safety, and may thus be viewed as a model for the occupational sector [40]. It is thus no wonder that the scientific community emphasizes the importance of continuing such initiatives in order to broaden their effect and achieve long-term success [42]. This might be especially senseful in consideration of the fact that, after the comprehensive preventive efforts of the Australian government, skin cancer rates are decreasing in this country, whereas globally, the contrary is the case [43].

Another very recent promising example of practical deployment of sun safety measures is to be found in the Netherlands. It has recently been reported in the newspapers that in the summer of 2023, in this country two approaches for an increased protective use of sunscreens are employed: (i) re-assignment of hand sanitizer dispensers—which were primarily needed for providing hand disinfectants for combating the COVID-19 pandemic—into sunscreen dispensers (e.g., in a hospital in Venlo, The Netherlands) and (ii) free provision of sunscreen with pump dispensers for visitors of selected outdoor festivals and people in city parks, at beaches, in schools and sports clubs. As studies were able to show that provision of skin products in the workplace promotes usage frequency [44,45], it can be assumed that this free supply might increase the frequency of use of sunscreen products. Even though this example from the Netherlands has taken place in the leisure sector, this might also act as a *blueprint* approach for the occupational field, in terms of deploying practical and easy sun safety measures.

3. Advancements in Prevention of Occupational Skin Cancer

3.1. Dosimetric Measurement Campaigns

In recent years, utilization of objective dosimetric measurements has helped in the identification of particular risk groups amongst outdoor workers [1,46–49]. It was found that it is the employment and tasks connected with this activity within the industrial sector that are problematic, not the industrial sector as a whole [1,47,48]. As has been shown, the use of personal dosimeters for measurement of solar UVR exposure at work is feasible, not only from a technical but also from a practical view, and might thus be used in the occupational setting routinely [50].

The German statutory social accident insurance adopted the mathematical model of "Wittlich's algorithm" to evaluate individual occupational lifetime solar UVR exposure based on gathered dosimetric data, which has since been utilized for improving prevention strategies, medical care options, and reimbursement for impacted workers [47]. Wittlich's algorithm takes into account for example the season, the time of the day, and the altitude of UVR exposure at the workplace. If, by this calculation, a person's lifetime UVR exposure increases by 40% through workplace exposure, it is expected that their risk of developing AK/SCC doubles and therefore, this is the individual threshold minimum UVR exposure dose that entitles for acknowledgement of multiple AK (<5) and/or an invasive SCC as an occupational disease in Germany. Obviously, only such skin cancer lesions can be acknowledged that develop in body areas occupationally exposed to UVR. Each year, over 5000 cases of occupational skin cancer are acknowledged, making it the second most frequent occupational disease and the most frequent one that leads to compensation payments (>800 cases per year). Given that the unique dosimetric measuring campaign in Germany by Wittlich et al. revealed unexpectedly high occupational exposures of up to 650 SED per summer period [21], outdoor workers typically meet the aforementioned requirement if they work for more than 10 years full-time in a high-risk profession [48]. This dosimetric measurement campaign '**GEN**eration and **E**xtraction **S**ystem for **I**ndividual expo**S**ure' (GENESIS-UV) used state-of-the-art dosimetric technology, also assessing the main angle of exposure. Wittlich et al. recruited 1000 participants who wore electronic data logger dosimeters during their working hours for a duration of 7 months each, from April to October, yielding 3.7 billion data points for around 48,000 days, covering more than 250 occupations and 650 work activities [51]. With this, the researchers were able to show that annual irradiances of the different occupations span a wide range of values from around 650 to 50 SED, including varying distributions over the months [51]. Also, the majority of observed workers regularly exceeded the above-mentioned recommendations at threshold limits of 1 to 1.3 SED/day by 5 times or more. It can be assumed that this provided data compendium will find rapid entrance into use in daily preventive practice, potentially even discharging into a European skin cancer database in the future [52]. Furthermore, other studies collecting dosimetric data found similarly high solar UVR exposure in outdoor workers, making clear that the described problem is not only a local one; For example, Rydz et al. collected 883 measurements from 179 outdoor workers and found that they were, on average, exposed to 1.93 SED (range: 0.03–16.63 SED) per day during the summer of 2019 in Alberta, Canada, and Moldovan et al. collected dosimetric data in two groups of 10 outdoor workers in Romania, located at two different geographic sites for a period of 7 months, from April to October, and found values in outdoor workers ranging from 1.28 to 6.4 SED per day [46].

It seems advisable that dosimetric data are collected in different countries all over the world in order to the able to depict the situation of the affected outdoor workers adequately, as well as to adapt sun protection advice and measures, if necessary. In this realm, another currently on-going state-of-the-art dosimetric measurement campaign should be mentioned: The 'Digitally **MEA**suring Solar Ultraviolet Radiation in **O**utdoor **W**orkers' (MEAOW) project, which is deployed in Lisbon Municipality, Portugal [53]. In the MEAOW project, personal electronic dosimeters following GENESIS-UV are being used by various outdoor workers. Given Lisbon's latitude and the nature of the work, it is reasonable to assume that outdoor workers occupational solar UVR doses will once more be significantly higher than the threshold level. Again, better knowledge about exposure will aid proficient design of tailored preventive measures. Hopefully, in the long run, this study, and others [21,46,54], will educate the public and decision makers about the core issue of an excess of skin cancers caused by occupational exposure to solar UVR.

It should be mentioned that in recent years, portable, or rather wearable, sensors for monitoring personal solar UVR exposure have also been developed, many of them also connectable with a smartphone application [55]. According to an overview by Huang and Chalmers, those sensors span wearable units, epidermal patches, clips for personal items (e.g., caps or collars), bracelets, wristbands, wrist attachments, wristwatches, and handheld devices [56]. Primarily, these sensors are developed to fit the needs in a private setting, but the future will show whether these tools might also be helpful in the occupational sector. It might be assumed that such technology, especially when affordable in purchasing and maintaining, as well as easy to implement, could be helpful in improving individual sun protection behavior, situatively.

3.2. Occupational Sunscreen Use

Sunscreen use is a key component of a comprehensive plan to limit solar UVR exposure at the workplace [40]. As mentioned above, sunscreen use belongs to the person-related measures according to the TOP principle and should only be used when i) the preceding technical and organizational measures cannot be deployed and ii) the body area cannot be covered by textile sun protection (mostly only the face, as well as the back of the hands) [18,34,40]. A common challenge encountered in practice is applying the correct, or rather a sufficient, amount of sunscreen, which is often not achieved in practice [57]. As has been shown in the scientific literature, oftentimes only an amount of sunscreen between 0.5 and 1.5 mg per cm^2 of skin is used [58,59]. However, in order to achieve the optimal protection, or rather the advertised SPF, an amount of 2.0 mg sunscreen per cm^2 of skin is needed. As lower amounts of sunscreen reduce the SPF exponentially, it should be advertised not to skimp on the amount of sunscreen used. To better estimate the correct amount of sunscreen, the 'rule of nines' or '11 zones $\times$ 2 fingers rule' was introduced by Taylor and Diffey [59]. According to this rule, two strips of sunscreen are applied from the tip to the base of the index and middle fingers, and this amount is applied to predefined areas. For the head, face and neck, this aforementioned amount is to be regarded as sufficient. As this is a *one-size-fits-all approach* it can be used in the sense of a rule of thumb. It should, however, be mentioned that some individuals might not reach sufficient and some excessive protection by this method, as sizes of faces and hands vary. In doubt, from a sun safety point of view, it is better to be over-protected than ill-protected.

The cosmetics industry nowadays offers a wide range of different sunscreens, ranging from creams to gels or lotions to sprays. In general, when choosing a suitable sunscreen that is tailored to the skin type, care should be taken to ensure that, for example, in skin that tends to dryness sunscreen with a higher lipid content can be used, while oily skin benefits from lighter cream-gel textures. This basic recommendation is derived for leisure solar UVR exposure and might not satisfy the requirements of physically active outdoor workers, which might be one of the reasons why compliance to using sunscreens at the workplace is oftentimes rather poor [39].

Furthermore, in the last few years, some topical agents complementary to sunscreens were discussed in the scientific community, which should also be mentioned. These topical agents for skin cancer prevention focus mainly on the mechanisms of boosting reparation of DNA (e.g., nicotinamide [also known as vitamin B3], green tea polyphenols, and DNA repair enzymes, such as topical T4 endonuclease V [T4N5] or photolyase), as well as modulating DNA transcription (e.g., retinoids) and decreasing inflammation (e.g., cyclooxygenase-2 (COX-2) inhibitors) [60]. Future application studies will likely show to what extent these topical agents for skin cancer prevention can and will be embedded within the current concepts of (occupational) skin cancer prevention.

It should be highlighted that there are presently no standardized test protocols for establishing if sunscreens are appropriate for usage in the workplace [40]. For this reason, a recent pilot study from Germany by Rocholl et al. [39] aimed at developing objective, standardized methods for assessing secondary performance attributes of sunscreens. In this, the bio-stability on the skin, when being physically active (i.e., resistance to sweat), eye irritation (burning), the absorption time, grip and subjective skin feeling, compatibility with textiles, dust and dirt absorption, as well as a whitening effect were included [39]. The study presented the following central results: (i) the test procedures employed were generally viable and suitable to evaluate the aforementioned performance attributes because they mimic real-world working settings, (ii) the products' advertised SPF has been verified; most of the time, the SPF bio-stability following physical activity was attained, and (iii) the subjective skin feel and non-slip grip were usually not evaluated [39]. These new techniques make it possible to create sunscreens that are specifically made for use while working outside [39]. To the best of our knowledge, to date there are—at least in Germany—no generally accepted, standardized criteria or mandatory testing schemes for skin products commercially offered as occupational sunscreens. In terms of quality assurance, such a standard would be highly useful, but time will show whether such a concept can and will be established. Until then, the above-mentioned criteria can provide guidance, also for manufacturers of (occupational) sunscreens.

In addition to assessing secondary performance attributes of sunscreens, it might be advisable to also pay attention to the overall acceptance of sunscreens amongst users. A current study looking at the important parameters regarding the acceptance of occupational skin products found that this might be highly influenced by parameters such as self-assessed skin tolerance and self-reported overall satisfaction [61]. As sunscreens also belong to the category of occupational skin products, the results of the aforementioned study might be applicable in this situation. Due to the results of the study by Symanzik et al., it can be assumed for sunscreens that they are only used as recommended if they are well-accepted by the workers who use them [61]. It seems advisable that further (controlled) intervention studies be conducted in the future in terms of occupational skin cancer prevention, with a specific focus on the high-risk group of outdoor workers. In these studies, the concept of user acceptance of sunscreen products should be examined in depth to pave the way for a profound understanding of the importance of this concept in the sun protection behavior of outdoor workers.

3.3. Sun Safety Interventions and Health Education

Studies from different countries have shown that among outdoor workers, the risk for developing occupational skin cancer is highly underestimated and the use of sun protection at work is widely neglected [62–64]. Generally, it must be assumed that outdoor workers (i) underestimate their risk of developing skin cancer and (ii) do not regularly utilize sun protection measures (e.g., sunscreens) correctly [63]. A very recent study by

Keurentjes et al. has found that sunscreen use *at the workplace* might remain low even if it is provided free of charge in a convenient way (i.e., sunscreen dispensers) [65]. Therefore, educational interventions to enhance outdoor workers' sun protection behavior are pivotal, as has been previously noted [34,37]. The risk perceptions and beliefs of outdoor workers concerning sun protection strategies ought to be considered when planning interventions, as a recent study indicates that these factors may have an influence on factual sun safety behaviors at work [63]. Fortunately, a range of current studies was able to show that many occupational groups are generally willing to improve their sun protection behavior if addressed properly [1,39,66].

One example is a patient counseling methodology for individualized sun protection, which was put to the test in a recent German investigation including outdoor workers who have been diagnosed with SCC or numerous AK as a result of occupational solar UVR exposure [66]. The 'counseling method for personalized sun protection' consists of seven general and eight add-on modules that may be combined and customized to the patient's particular needs; interactive instructional components (for example, haptic experiments) are essential elements of the program [66]. Another finding from the study was that despite widespread support for improved sun protection practices across particular occupational groups sun safety programs seldom consider the unique demands of outdoor workers [66]. This very important finding may help to better design target-oriented and well-accepted sun safety measures. Ludewig et al.'s [66] strategy's advantage is its flexibility to adapt its many components to patients' various needs.

The "ForMulA UV 1.0 & 2.0" initiatives, which sought to create and evaluate a scientifically grounded, standardized, target group-specific curriculum as an additional training program for multipliers in outdoor professions, demonstrated that the intended audience has a variety of criteria (such as complexity of material), both at the level of outdoor workers and at the level of various multiplier groups (such as occupational safety professionals), which should be acknowledged within the framework of considerations regarding sun safety measures [67]. A theoretically grounded, target group-focused curriculum that was reported in compliance with the "Template for Intervention, Description and Replication" (TIDieR) [68] was obtained from this project [67]. Additionally, it was shown that creating cross-target group curricula that are appropriate in a variety of professional areas can only be partially feasible; the effectiveness of preventative measures depends heavily on changes made on the job by proficient multipliers [67]. Further research on the efficacy of strategies to prevent occupational skin cancer in outdoor workers appears essential in order to provide valid evidence for a real decline in the prevalence of skin cancer in this sector [69].

3.4. Biomarkers of Ultraviolet Radiation Exposure

Due to the rapidly rising prevalence of skin cancer, the need for non-invasive biomarkers to evaluate the effectiveness of preventative measures targeted at lowering solar UVR exposure has been recognized. In a recent study from the Netherlands by Keurentjes et al. [70], *stratum corneum* biomarkers that were isolated from tape strips were looked at as potential solar UVR exposure markers. It was discovered that *stratum corneum* biomarkers may offer a possible, non-invasive substitute for skin biopsy in identifying changes caused by solar UVR [70]. Urocanic acid (cUCA) may be used as a marker for evaluating a single solar UVR exposure, while for assessing chronic solar UVR exposure, immunological markers like interleukin-1 receptor antagonist/interleukin-1 alpha (IL-1RA/IL-1) and placental growth factor (PGF) may be utilized [70]. Also, the aforementioned research group found that cUCA presents a sensitive, non-invasive marker of the solar UVR dose, which allows in vivo assessment of the UV-B blocking effect of sunscreens with a high SPF [71]. Keurentjes et al. [65] concluded that collection of *stratum corneum* samples at the workplace is feasible—as well as easy, simple, and painless for the participant—and several biomarkers (i.e., cUCA, interleukin (IL)-18, IL-8, CC-chemokine ligand 27 (CCL27), and granulocyte-macrophage colony-stimulating factor (GM-CSF)) showed to be promising in assessing

UVR exposure. The above-mentioned biomarkers are currently only utilized in experimental studies and not in routine care. However, such test procedures are likely to become more important in the future, especially if the evidence base justifies their integration into routine care. From an ethical point of view, tape stripping procedures can be considered innocuous because they are a non-invasive method and no relevant harm is expected for the sampled persons. These aforementioned biomarkers may, in the future, be able to assist in evaluating the success of preventative measures in the workplace [40]. Regarding taking the necessary samples in the occupational field, occupational physicians or occupational safety specialists could also be involved, as the sample taking is easily learned and not difficult or disproportionately expensive to implement in daily practice [72].

4. Conclusions

Outdoor workers comprise a high-risk group for the development of occupational skin cancer due to solar UVR exposure, mainly manifesting as AK or SCC [18,37]. Currently, there are various measures of primary, secondary, and tertiary prevention available, which are utilized with an onset at different points in time [73]. In prevention of occupational skin cancer caused by solar UVR exposure, it is most important to limit the quantity of solar UV exposure of the workers [34]. Sun safety measures should follow the hierarchical TOP principle, spanning technical, organizational, and person-related measures [35,36]. In terms of recent advancements regarding the prevention of occupational skin cancer caused by solar UVR exposure, contemporary dosimetric measurement campaigns aiding in the identification of particular risk groups amongst outdoor workers [1,46–49], current recommendations for the use of sunscreens, as well as objective and standardized assessment methods of performance attributes of occupational sunscreens making it possible to create sunscreen that is specifically made for use while working outside in the future [39], and novel approaches in terms of sun safety interventions and health education measures [66,67] can be named. On the contrary, there continues to be a lack of recognition of occupational skin cancer cases, confirmation regarding the efficacy of health surveillance programs and screenings for high-risk groups of outdoor workers, cancer case reimbursement, and political comprehension and acknowledgement of this growing health issue tied to the occupation [10,33,74]. In order to effectively address the current and upcoming issues, it must be suggested that the full range of preventative measures are employed to fight occupational skin cancer [37].

Author Contributions: Conceptualization, C.S.; resources, S.M.J.; writing—original draft preparation, C.S.; writing—review and editing, S.M.J.; visualization, C.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable. This paper does not contain any studies with human participants performed by any of the authors. This paper does not contain any studies with animals performed by any of the authors.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing is not applicable to this article as no new data were created or analyzed in this paper.

Conflicts of Interest: The authors declare no conflict of interest.

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