Photochemical & Photobiological Sciences (2023) 22:1213–1222
https://doi.org/10.1007/s43630-023-00385-6

PERSPECTIVES

Photoprotection in occupational dermatology

Cara Symanzik[1,2] · Michaela Ludewig[1,2] · Marc Rocholl[1,2] · Swen Malte John[1,2]

Received: 9 May 2022 / Accepted: 30 January 2023 / Published online: 28 February 2023

Abstract
Skin cancer has become a substantial matter of public health and in the workplace, accounting for a significant share of all reported occupational diseases. The most important external factor in the development of skin cancer is exposure to solar ultraviolet radiation. Outdoor workers have already been identified as a high-risk category. The need for interventions to improve the sun protection behavior of outdoor workers has recently been understood. Outdoor workers' risk perceptions and attitudes toward sun protection methods are likely to influence practical sun protection behavior at work, and despite the fact that many workers have expressed interest in improving their sun protection behavior, outdoor workers' unique needs are still neglected. Occupational dermatology is predicted to become more concerned with photoprotection in the decades ahead. Preventive action against the rapidly increasing number skin cancer cases is in great demand around the globe. In terms of preventive measures, the full range of available options should be used as needed to address the current difficulties in a goal-oriented way. This will almost certainly only be achievable if preventative efforts on a collective and individual level are successfully paired with support from policymakers to inspire long-term change.

Keywords Non-melanoma skin cancer · Prevention · Skin cancer · Occupation · Outdoor work · Ultraviolet radiation

1 Introduction

Skin cancer in the workplace accounts for a significant portion of all reported occupational illnesses [1]. The number of people diagnosed with skin cancer has progressively expanded in the last few decades [2, 3]. As a result, skin cancer has become a serious public health concern in fair-skinned populations around the world; exposure to solar ultraviolet radiation (UVR) is the most critical external factor in causing skin cancer [4]. Outdoor workers have lately become the focus of scientific attention as a high-risk population [1, 5, 6]. Solar UVR is by far the most relevant occupational carcinogenic exposure in relation to the number of workers exposed [7–9], as non-melanoma skin cancer (NMSC), more precisely described as keratinocyte carcinoma (KC) [10], which manifests as actinic keratosis (AK, intra-epidermal SCC), invasive cutaneous squamous cell carcinoma (SCC), and/or basal cell carcinoma (BCC), is mainly caused by solar UVR [11–14]. Even though several recent studies have indicated a potential association between chronic occupational sun damage and some malignant melanoma (MM) subtypes, such as lentigo maligna melanoma (LMM), the correlation between (cumulative) occupational solar UVR exposure and MM is seen as not conclusive [12, 15]. In the development of MM, intermittent UVR exposure and particularly UVR exposure in children as well as genetic predispositions appear to play a more relevant role [16].

Regardless of the fact that millions of workers around the world are subjected to occupational carcinogenic exposure from solar UVR for a significant portion of their work hours, this work-related health risk is still not officially acknowledged by occupational safety and health (OSH) directives and regulations in many parts of the globe [11, 17, 18]. Further to that, no universally accepted occupational solar UVR exposure limit values exist; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has proposed an occupational solar UVR exposure limit of 1.0 to 1.3 Standard Erythema Doses (SED) per day; 1 SED equals 100 J/m^2 of the biologically weighted erythema

✉ Swen Malte John
johnderm@uni-osnabrueck.de

[1] Institute for Interdisciplinary Dermatological Prevention and Rehabilitation (iDerm), Osnabrück University, Osnabrück, Germany

[2] Department of Dermatology, Environmental Medicine and Health Theory, Institute for Health Research and Education (IGB), Faculty of Human Sciences, Osnabrück University, Am Finkenhügel 7a, 49076 Osnabrück, Germany

action spectrum [18, 19]. Among the adverse consequences of this under-recognition of health risks associated with solar UVR are a lack of case recognition, a lack of evidence on the effectiveness of health surveillance programs and screenings for high-risk groups of outdoor workers, a lack of indemnification for cases of cancer, and a lack of political understanding and acceptance of this growing work-related health concern [15, 20, 21]. Against this backdrop, this paper focuses on photoprotection in occupational dermatology.

2 Occupational risk groups for skin cancer by solar ultraviolet radiation

Outdoor workers are in particular subjected to excessive levels of solar UVR since they spend the majority of their work time outside [22]. As a consequence, those workers are much more prone than the general population to develop NMSC [11, 23]; their risk is at least twofold higher compared to the general population, with SCC being cancer most closely connected to cumulative solar UVR exposure [24, 25]. Construction workers, gardeners, fishermen, and farmers are examples of vocations that require a lot of outside work. Table 1 provides an overview of further occupations with occupational exposures to solar UVR.

3 Prevention

The operational area of workplace safety includes sun protection. To avoid skin malignancies induced by solar UVR exposure, outdoor workers must reduce their occupationally acquired solar UVR dosages. The amount of solar UVR exposure, the tasks to be performed in the sun, and the employees' solar UVR protective procedures are all essential elements in estimating cumulative sun exposure in outdoor workers. Recommendations for preventive measures are generally based on the so-called STOP principle, which includes technical, organizational, and person-related measures, as outlined in the following. All those measures focus on the reduction of the occupational solar UVR exposure in ascending order, i.e., the next step of measures should only be instigated if the previous stage has been exhausted to the full extent (Table 2).

At this juncture, a particular health campaign from Australia should be mentioned: The 'Slip, Slop, Slap' slogan, which was launched by Cancer Council in 1981 and updated in 2007 to 'Slip, Slop, Slap, Seek, Slide', reflects the significance of measures – in this case five steps – to prevent sun damage (**slip** on a long-sleeved shirt or sun protective clothing, **slop** on broad-spectrum sunscreen with a Sun Protection Factor (SPF) of 30 or greater, and re-apply every two hours, **slap** on a hat, the wider the brim the better, **seek** shade or

Table 1 Extract of vocations (sorted alphabetically) with direct (i.e., received directly from the sun, e.g., working outdoors without using any form of sun protection) and indirect (i.e., scattered by the atmosphere and/or reflective surfaces, e.g., working near water/sand/snow with the face becoming sunburnt despite wearing an adequate hat) occupational exposures to solar ultraviolet radiation (UVR) according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO)

Direct occupational solar UVR exposure	Indirect occupational solar UVR exposure
Agricultural workers	Aircraft maintenance engineers
Animal trainers	Building and construction managers
Bricklayers	Bulldozer operators
Builders	Caravan and camping ground stuff
Construction workers	Childcare workers
Drillers	Defense force staff
Earthmoving laborers	Door-to-door salespeople
Farm hands	Firefighters
Gardeners	Forklift operators
Jokeys	Motor mechanics
Leaflet or newspaper deliverers	Outdoor ushers and ticket people
Lifeguards	Panel beaters
Miners	Plumbers and assistants
Outdoor billboard and sign writers	Police officers
Outdoor car park attendants	Primary and secondary school teachers
Painters and decorators	Professional drivers
Roof tilers and slaters	Railway assistance
Sports people, coaches, and support persons	Street vendors
Sugarcane workers	Supermarket trolley collectors
Traffic controllers	Tree surgeons
Vegetable, fruit, and nut growers	Zoo workers

solar UVR, solar ultraviolet radiation

Table 2 Summary of measures according to the STOP principle (substitution, technical, organizational, and person-related) for the reduction of occupational solar ultraviolet radiation (UVR) exposure in ascending order [26]

Measure	Explanation	Example
S	Substitution	Replacing occupational health threats is usually the most important strategic factor in prevention (usually not feasible in outdoor vocations)
T	Technical	Technical measures to avoid exposure to sunlight
		All forms of shading are suitable (e.g., sun shields)
O	Organizational	Avoidance of outdoor work during peak solar UVR hours
		Shifting working hours away from the midday heat or rather Relocation of working hours in the early mornings or late afternoon
		Taking breaks in the shade
		Performing individual work tasks in the shade
P	Person-related	Protective clothing with ultraviolet protection factor (UPF), long-sleeved shirts, long trousers and gloves
		Protective brimmed headgear with neck and ear protection
		Eye protection by suitable sunglasses
		Broad-spectrum sunscreens (UV-A/UV-B, Sun Protection Factor (SPF) ≥ 30, preferably 50 +) should only be used if protection by other means is not possible; if used, adequate application in terms of frequency and amount is key

solar UVR, solar ultraviolet radiation; SPF, sun protection factor; UPF, ultraviolet protection factor; UV-A, ultraviolet; UV-B, ultraviolet B

shelter during peak sun exposure times, generally from 10 a.m. to 4 p.m., **slide** on UV-protective sunglasses to protect the eyes) [27]. Even if the campaign focuses on the leisure sector, it is aimed at the entire population, addresses central aspects that are also relevant for protection on the job and can therefore be seen as a *blueprint* for the occupational sector. Therefore, it is stressed by the scientific community that such campaigns need to continue in order to expand their influence to be successful in a sustainable manner [28].

3.1 Technical measures

Technical measures comprise—as a general rule and in terms of collective protection—all measures that can be used to avoid exposure to solar UVR. This can mainly be done with any type of shading, such as sun sails or weather protection tents, parasols, awnings or UVR protection foils for windows. Accordingly, work in the shade is generally preferable.

3.2 Organizational measures

Limiting outside work when the sun is shining brightly is one of the organizational measures. In terms of workplace safety, even altering working hours away from maximal solar UV exposure and the midday heat can be beneficial. This is especially true in Europe between April and September, from roughly 11 a.m. to 4 p.m Central European Summer Time (CEST) when > 80% of the daily UV-B emission occurs. Working hours should be moved to the early mornings or late afternoons, breaks should be taken in the shade, and if possible, individual job tasks should be completed in the shade.

Special considerations must be made for construction sites in mountains since solar UVR exposure is greater in these areas. The solar UVR exposure increases by about 10% for every 1000 m of altitude; i.e., the higher above sea level, the stronger the UV radiation. Snow or sand (and also water) reflect the UV rays and almost lead to an increased exposure of up to twofold of direct irradiance. Solar UVR rises beyond a UV-Index, which is a World Health Organization (WHO) recommended international standard measurement of the UVR strength at a particular place and time on a linear scale ranging from 0 to 11 +, of 3 ('moderate') already in spring in Northern Europe and lasts to late summer (April to September according to the German *Ordinance on Preventive Occupational Health Care* (ArbMedVV)) [29].

3.3 Person-related measures

Personal protection is the most appropriate form of protection for persons who will be in an outdoor setting for an extended period of time [26]. If health risks cannot be completely ruled out by deploying technical or organizational measures, the employer—in Germany—then has reasonably to provide effective Personal Protective Equipment (PPE). Conversely, the employee is obliged to use the PPE in an adequate manner. This individual prevention or rather prevention on a person-related level entails equipping outdoor workers with appropriate PPE, which includes a) eyewear with wide, UVR filtering lenses, b) UVR filtering garments (such as long-sleeved shirts and pants), and c) headwear (i.e., broad-brimmed helmets or hats with sun shields as well as ear and neck guards) [30, 31]. Sunscreens must block ultraviolet (UV)-A and UV-B rays, have an SPF of at least 30 but preferably greater (i.e., 50 +), and be water/sweat-resistant as

well as easy to apply so that they can be reapplied regularly during the day [30–33]. Sunscreens should only be used in areas (e.g., facial area) which cannot be protected otherwise, i.e., by clothing. It should be noted that the claimed SPF can only be achieved by adequately applying the sunscreen in a sufficient amount of 2 mg/cm^2. This can be achieved with the help of the so-called two-finger rule, which advises to squeeze two strips of sunscreen from the tip to the base of the index and middle finger and apply this amount to predefined areas: head, face, and neck; left arm; right arm; upper back; lower back; chest (upper torso area); stomach (lower torso area); left upper leg and thigh; right upper leg and thigh; lower left leg and foot; lower right leg and foot.

4 Challenges in prevention

Outdoor workers, being predominantly male, are likely to be unaware of skin cancer, engage in risky behavior, and might have poorer health literacy [4, 26]. As a result, customized health education for outdoor workers is critical in promoting sun-smart behavior; all outdoor workers should have access to secondary prevention (i.e., strategies leading to the early identification of precancerous states or malignancies) for early skin cancer detection [26]. The health dangers of solar UVR exposure in the workplace are mainly disregarded, and the evident future concerns are contrasted with the current situation in terms of legal recognition, patient treatment, and compensation [1]. Improved protection through legally enforceable laws and regulations is an important factor in minimizing cancer risks for outdoor workers [1]. Fields of activity concerning NMSC patients' unmet needs according to the global Call to Action, launched on 26 April 2019 at the 1st Multi-Stakeholder Summit on Occupational Skin Cancer, held in Paris on the occasion of the 15th European Association of Dermato Oncology (EADO) Congress (24–27 April 2019) [1] are summarized in Table 3.

Dermatologists will play an increasingly important role in enhancing patient care and outcomes in dermato-oncology in the long term [1], particularly in light of innovative diagnostic techniques and treatment options for early and advanced skin cancer, as well as the increasingly diversified skills, understanding, and knowledge needed to manage this heterogeneous range of disorders, in this context [3]. In the case of occupational causality, it is critical that cases be reported to the appropriate authorities. Recently, open-access notification forms for reporting suspected cases to the appropriate authorities were published [34].

4.1 Outdoor workers' perceptions of skin cancer risk and photoprotection attitudes

The urgent requirement for interventions aimed at improving outdoor workers' sun protection behavior has been identified by the scientific community. Whilst developing such prevention programs, the attitudes of target populations must be considered to ensure practical orientation [35, 36]. A study in Germany was undertaken to determine outdoor workers' perceptions and attitudes, and the results revealed an underestimating of the perceived danger of skin cancer in the interviewed outdoor employees, as well as varied attitudes regarding the use of sun-protective measures [37]. The feasibility of carrying out technical sun-protective measures (e.g., providing shade by using sun sails), according to participants, is highly dependent on the magnitude of the working area [37]. Although wearing a hat seems to be the norm, none of the participants mentioned wearing neck protection; moreover, wearing long-sleeved shirts and long pants was deemed inappropriate [37]. Important criteria for sun-protective clothing emerged from the interviews, particularly in terms of diverse materials [37]. Although sunscreen was

Table 3 Recommendations to prospectively address the unmet needs of NMSC patients [1]

Number	Recommendation
1	Policymakers should enhance the legal framework to better safeguard outdoor workers and provide access to frequent screenings and, as a result, early treatment
	NMSC by solar UVR should be recognized as an occupational disease in the European Union within the next legislative period
2	Doctors, other health professionals, and politicians should collaborate to ensure that NMSC registration in population-based cancer registries is harmonized across the European Union
3	Employers should utilize technologies to track levels of solar UVR exposure in the workplace. They must also develop cost-effective methods for sun-safe behavior and assure that outdoor workers receive regular skin cancer screenings
4	Occupational NMSC (including actinic keratosis) should be considerably better reported to accident insurances by doctors and other health professionals
5	Patient advocacy organizations, doctors, and other healthcare professionals, as well as employers, should work together to increase skin cancer prevention and sun-safe work conditions, as well as to answer the unmet needs of retired outdoor workers experiencing NMSC

NMSC, non-melanoma skin cancer; solar UVR, solar ultraviolet radiation

widely used, most participants appeared to apply it in an incorrect manner (e.g., frequency and/or amount of sunscreen) [37].

It is fair to conclude that outdoor workers' risk perceptions and attitudes toward sun protection measures may have an impact on actual solar UVR protection behavior in the workplace [37]. It appears that structures are required to ease the deployment of technical and organizational sun-protective measures. In order to improve solar UVR protection behavior and avoid common mistakes in UVR protection, educational interventions and clear instructions targeted to the unique requirements and attitudes of outdoor workers are required [37].

4.2 Photoprotection as a standard in outdoor workers

In a recent study from Germany, a patient counseling method for customized sun protection was developed and pilot tested for individuals in outdoor professions diagnosed with squamous cell carcinoma or multiple actinic keratosis due to solar UVR [38]. The 'counseling approach for individual sun protection' comprised seven general and eight add-on modules that can be combined and tailored to the patient's specific needs—interactive, educational components (e.g. haptic experiments) are critical aspects of the counseling approach [38].

In this study, it was also demonstrated that, despite a high level of interest in enhanced sun protection behavior across specific occupational groups, the special needs of outdoor workers are rarely considered in Germany [38]. This correlates with current recommendations to prospectively address the unmet needs of NMSC patients (Table 2), especially that employers should use technology to track solar UVR exposure in the workplace, establish cost-effective strategies for sun-safe behavior, and ensure that outdoor workers are getting regular skin cancer screenings, and that patient advocacy organizations, doctors, and other healthcare professionals, as well as employers, should collaborate to improve skin cancer prevention and sun-safe workplace conditions [1]. The explicit benefit of the proposed strategy is that its numerous modules can be tailored to meet the diverse demands of patients [38]. This concept could moreover be further developed in the future.

Moreover, the projects "ForMulA UV 1.0 & 2.0" should be mentioned, which aimed to design and pilot a scientifically based, standardized, target group-specific curriculum as a further training program for multipliers in outdoor professions. Those projects revealed diverse requirements (e.g., depth of content) of the intended audience, i.e., both at the level of outdoor workers and at the level of various multiplier groups (e.g., occupational safety specialists) [39]. A scientifically based, target group-oriented curriculum—reported in accordance with the "Template for Intervention, Description and Replication" (TIDieR) [40]—could be made available with this aforementioned project [39]. It has also been demonstrated that developing a cross-target group curriculum suitable for diverse professional domains is only practicable to a limited extent; modifications made on the job by qualified multipliers are crucial to the efficacy of prevention measures [39].

4.3 New methods for assessing the performance of sunscreens

As acknowledged in a recent study from Germany, sunscreens are an essential part of an overall strategy to reduce workplace solar UVR exposure, but compliance with routine sunscreen use appears to be low, as products are typically designed for leisure sun exposure and do not satisfy the requirements of physically active outdoor workers [33]. It should be noted that there are currently no standardized test procedures for determining the suitability of sunscreens for professional use; thus, the goal of the aforementioned pilot study was to develop standardized methods for evaluating secondary performance attributes (i.e., bio-stability on the skin when being physically active (i.e., resistance to sweat), eye irritation (burning), absorption time, grip and subjective skin feeling, compatibility with textiles, dust and dirt absorption, whitening effect) to simulate real-life working conditions of outdoor work [33].

Following central results could be gained [33]:

Although the degree of discriminability of particular test methods varied (i.e., barely any differences in the raw data were seen for the test procedures regarding eye irritation when sweating (burning), compatibility with textiles, as well as dust and dirt absorption), the test procedures used are overall viable and appropriate for testing the aforementioned performance attributes since they accurately simulate real-world working settings.
The products' advertised SPF was confirmed, and the SPF bio-stability following physical activity was reached in the majority of cases.
While most treatments do not irritate the eyes and are quickly absorbed, the subjective skin feel and non-slip grip are usually not evaluated.

These new methods allow for sunscreens to be specially designed for usage in outdoor work and it is thereby to be expected that adoption in professional outdoor employment is increasingly promoted [33].

5 Future perspectives

The need for interventions to improve outdoor workers' sun protection behavior has already been acknowledged. Outdoor workers' risk perceptions and attitudes toward sun protection methods likely influence practical sun protection behavior at work, and despite the fact that some occupational groups have indicated an interest in improving their sun protection behavior [38], the special demands of outdoor workers are still insufficiently recognized [37]. Dominant evidence suggests that structures are required to enable the implementation of technical and organizational sun-protective measures, and that educational interventions and clear instructions tailored to the specific needs and attitudes of outdoor workers are required to improve solar UVR protection behavior and alleviate widespread sun-protection mistakes [1, 33, 38]. Due to the rapidly increasing prevalence of skin cancer, this disease has been put on the political agenda in some parts of the globe. Future perspectives span new methods for assessing the efficacy of prevention strategies (i.e., non-invasive biomarkers), legal challenges as well as priorities on dermato-oncology, which will be discussed in the following.

5.1 Biomarkers of ultraviolet radiation exposure

The need for non-invasive biomarkers to assess the success of preventative strategies aimed at reducing solar UVR exposure has been identified as a result of the fast-increasing prevalence of skin cancer. Recently, stratum corneum biomarkers, extracted from so-called tape strips, were investigated as possible indicators for solar UVR in a study from the Netherlands [41]. This study found that stratum corneum biomarkers provide a potential, non-invasive alternative to skin biopsy in detecting solar UVR-induced alterations, with urocanic acid (cUCA) as a marker for single solar UVR-exposure evaluation and immunological markers, such as interleukin-1 receptor antagonist/interleukin-1 alpha (IL-1RA/IL-1α) and placental growth factor (PGF), for monitoring chronic solar UVR exposure [41]. cUCA is also a sensitive, non-invasive marker of the solar UVR dose, allowing in vivo assessment of the blocking effect of high SPF sunscreens in the UV-B-region, according to the same research team from the Netherlands [42]. It thus seems promising, that these biomarkers prospectively also could help in assessing the effectiveness of preventive actions in the workplace and in the wider public.

5.2 Priorities in dermato-oncology

The lack of adoption of sun-protective activities and routines by outdoor workers is indicated by a wide range of research reporting high levels of individual solar UVR exposure at work and inadequate adoption of sun-protective activities and routines by outdoor employees. Inadequate implementation of effective preventive treatments in outdoor workers is hampered by the negligence towards the occupational risks of developing skin cancer [17, 43, 44]. Against this background, priorities of the future in dermato-oncology (Table 4) have been laid down in a position paper of the European Association of Dermato Oncology (EADO), European Academy of Dermatology and Venereology (EADV) and Task Forces, European Dermatology Forum (EDF), International Dermoscopy Society (IDS), European Board of Dermato-Venereology at the European Union of Medical Specialists (EBDV–UEMS) and European Organisation for Research and Treatment of Cancer (EORTC) Cutaneous

Table 4 Future priorities in dermato-oncology in terms of primary, secondary, and tertiary prevention [3]

Classification	Concrete actions
Primary prevention	Health educational measures, such as specialized health-pedagogical training programs
	Organization of campaigns and other initiatives in collaboration with authorities and scientific groups
	Legislators working together to reform laws about solar UVR exposure
Secondary prevention	Conception and execution of health education interventions, such as encouraging self-examinations and seeking physician skin examinations, or teaching non-healthcare professionals (e.g., hairdressers) on skin cancer identification
	Organization of campaigns and other initiatives in collaboration with authorities and scientific groups
	Developing standards and deciding on the best population to test
	Developing a framework for healthcare providers to get continuing and updated training
Tertiary prevention	Creating unified patient management algorithms
	Encourage the formation of interdisciplinary cancer boards for more complicated issues
	Working with healthcare providers to improve patient access to novel treatments
	Improving patient access to randomized controlled trials

solar UVR, solar ultraviolet radiation

Lymphoma Task Force [3]. Measures of primary prevention (i.e., efforts to minimize solar UVR exposure in the general population and at-risk populations), secondary prevention (i.e., strategies that can lead to the identification of precancerous states or malignancies in an early phase), and tertiary prevention alongside expansion and improvement of skin cancer registries (i.e., monitoring the existing situation, assessing the effectiveness of preventive initiatives, and designing effective interventions) are prospectively required to effectively combat occupational skin cancer caused by solar UVR [3].

5.3 Legal framework and legislation

Regrettably, even in the few countries where NMSC is recognized as an occupational disease, impacted workers are largely denied the benefits of legal recognition due to widespread underreporting: the responsible physician or dermatologist does not notify, as the disease-occupation link is not yet routinely established [1]. Since skin cancer was added to the list of occupational disorders in 2000, only 36 instances have been reported in Denmark [45]. The situation is similar in Italy, where solar UVR-induced NMSC is also on the national occupational illnesses list: on average, only 34 cases were recorded annually between 2002 and 2017 [15], with similar underreporting in other countries [21]. When various kinds of NMSC (SCC, multiple AK) were legally included in the national decree of occupational diseases in Germany in 2015, the situation changed. Over 7,700 cases of occupational skin cancer were reported in the first year after it was implemented. In 2019, there were 9,931 notifications, making skin cancer the third most commonly reported occupational condition and the second most commonly legally recognized illness. It's worth noting that a monetary incentive has been put in place to encourage physicians to report, which has contributed to the high notification rates. Patients who have been diagnosed with occupational skin cancer are provided with priority medical attention and compensation. The unusually high solar UVR exposures in outdoor workers, as revealed by recent measurement projects in this country [46] and elsewhere [18, 22, 47–50], along with the dramatically increasing number of skin cancer notifications, has enabled a breakthrough in German health and safety regulations. Employers must complete a unique solar UVR exposure risk assessment, provide personal protective equipment (including sunscreens), and offer solar UVR-exposed personnel a consultation in a three-year rhythm by an occupational physician for the first time as of July 12, 2019 [51].

The recent German experience demonstrates that politicians only feel compelled to act when there are notifications. As a result, the 11th edition of the WHO International Classification of Diseases (ICD), which was accepted on May 25, 2019, can be seen as a significant step forward in addressing underreporting and obtaining more accurate and objective disease data on a worldwide scale. For the first time, NMSC, including AK, can be classed as occupational and BCC as well as SCC are now distinct categories [52]. As a result, ICD 11, which has taken effect on January 1, 2022, will likely show the full epidemiological extent of work-related solar UVR-induced skin cancer and could give crucial new worldwide public health statistics for cancer prevention among outdoor workers [1]. A current study has highlighted the present scarcity of information on skin cancer in solar UVR-exposed employees in many parts of the world. [11]. The WHO and the International Labour Organization (ILO) are presently examining the global disease burden of NMSC—under the United Nations (UN) Sustainable Development Goals 2030 framework—due to the urgent nature of the rising number of NMSC cases associated with occupational solar UVR exposure. Solar UVR exposure has been recognized by both UN agencies as one of the ten most important occupational risk factors; the health outcomes have yet never been included in prior global estimating techniques but are extremely likely to account for a significant disease burden [5, 6].

6 Conclusion

Photoprotection will expectedly concern the field of occupational dermatology further over the coming decades. There is a strikingly high demand for taking preventive action against the rapidly increasing numbers of skin cancer worldwide. Regarding preventive measures, the whole range of available actions should be utilized, as appropriate, in order to meet the prevailing challenges in a goal-oriented manner. This will foreseeably only be possible when preventive measures on a collective and individual level are successfully combined with support from leading policymakers as well as foremost experts so that sustainable changes can be stimulated.

Funding Open Access funding enabled and organized by Projekt DEAL. No funds, grants, or other support was received.

Data availability Data sharing is not applicable to this article as no datasets were generated.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

1. John, S. M., Garbe, C., French, L. E., Takala, J., Yared, W., Cardone, A., et al. (2021). Improved protection of outdoor workers from solar ultraviolet radiation: Position statement. *Journal of the European Academy of Dermatology and Venereology, 35*(6), 1278–1284. https://doi.org/10.1111/jdv.17011
2. Park, Y. J., Kwon, G. H., Kim, J. O., Kim, N. K., Ryu, W. S., & Lee, K. S. (2020). A retrospective study of changes in skin cancer characteristics over 11 years. *Archives of Craniofacial Surgery, 21*(2), 87–91. https://doi.org/10.7181/acfs.2020.00024
3. Garbe, C., Peris, K., Soura, E., Forsea, A. M., Hauschild, A., Arenbergerova, M., et al. (2020). The evolving field of Dermato-oncology and the role of dermatologists: Position Paper of the EADO, EADV and Task Forces, EDF, IDS, EBDV-UEMS and EORTC Cutaneous Lymphoma Task Force. *Journal of the European Academy of Dermatology and Venereology, 34*(10), 2183–2197. https://doi.org/10.1111/jdv.16849
4. Trakatelli, M., Barkitzi, K., Apap, C., Majewski, S., & De Vries, E. (2016). Skin cancer risk in outdoor workers: A European multicenter case-control study. *Journal of the European Academy of Dermatology and Venereology, 30*(Suppl 3), 5–11. https://doi.org/10.1111/jdv.13603
5. Paulo, M. S., Adam, B., Akagwu, C., Akparibo, I., Al-Rifai, R. H., Bazrafshan, S., et al. (2019). WHO/ILO work-related burden of disease and injury: Protocol for systematic reviews of occupational exposure to solar ultraviolet radiation and of the effect of occupational exposure to solar ultraviolet radiation on melanoma and non-melanoma skin cancer. *Environment International, 126*, 804–815. https://doi.org/10.1016/j.envint.2018.09.039
6. Boniol, M., Hosseini, B., Ivanov, I., Náfrádi, B., Neira, M., Olsson, A., et al. (2021). *The effect of occupational exposure to solar ultraviolet radiation on malignant skin melanoma and nonmelanoma skin cancer: A systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury*. Geneva: World Health Organization.
7. Peters, C. E., Ge, C. B., Hall, A. L., Davies, H. W., & Demers, P. A. (2015). CAREX Canada: An enhanced model for assessing occupational carcinogen exposure. *Occupational and Environmental Medicine, 72*(1), 64–71. https://doi.org/10.1136/oemed-2014-102286
8. McKenzie, J. F., El-Zaemey, S., & Carey, R. N. (2020). Prevalence of exposure to multiple occupational carcinogens among exposed workers in Australia. *Occupational and Environmental Medicine*. https://doi.org/10.1136/oemed-2020-106629
9. Kauppinen, T., Toikkanen, J., Pedersen, D., Young, R., Ahrens, W., Boffetta, P., et al. (2000). Occupational exposure to carcinogens in the European Union. *Occupational and Environmental Medicine, 57*(1), 10–18. https://doi.org/10.1136/oem.57.1.10
10. Karimkhani, C., Boyers, L. N., Dellavalle, R. P., & Weinstock, M. A. (2015). It's time for "keratinocyte carcinoma" to replace the term "nonmelanoma skin cancer." *Journal of the American Academy of Dermatology, 72*(1), 186–187. https://doi.org/10.1016/j.jaad.2014.09.036
11. Loney, T., Paulo, M. S., Modenese, A., Gobba, F., Tenkate, T., Whiteman, D. C., et al. (2021). Global evidence on occupational sun exposure and keratinocyte cancers: A systematic review. *British Journal of Dermatology, 184*(2), 208–218. https://doi.org/10.1111/bjd.19152
12. Armstrong, B. K., & Kricker, A. (2001). The epidemiology of UV induced skin cancer. *Journal of Photochemistry and Photobiology B: Biology, 63*(1–3), 8–18. https://doi.org/10.1016/s1011-1344(01)00198-1
13. Fitzmaurice, C., Abate, D., Abbasi, N., Abbastabar, H., Abd-Allah, F., Abdel-Rahman, O., et al. (2019). Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 1990 to 2017: A systematic analysis for the global burden of disease study. *JAMA Oncology, 5*(12), 1749–1768. https://doi.org/10.1001/jamaoncol.2019.2996
14. Bauer, A., Diepgen, T. L., & Schmitt, J. (2011). Is occupational solar ultraviolet irradiation a relevant risk factor for basal cell carcinoma? A systematic review and meta-analysis of the epidemiological literature. *British Journal of Dermatology, 165*(3), 612–625. https://doi.org/10.1111/j.1365-2133.2011.10425.x
15. Gobba, F., Modenese, A., & John, S. M. (2019). Skin cancer in outdoor workers exposed to solar radiation: A largely underreported occupational disease in Italy. *Journal of the European Academy of Dermatology and Venereology, 33*(11), 2068–2074. https://doi.org/10.1111/jdv.15768
16. Watson, M., Holman, D. M., & Maguire-Eisen, M. (2016). Ultraviolet radiation exposure and its impact on skin cancer risk. *Seminars in Oncology Nursing, 32*(3), 241–254. https://doi.org/10.1016/j.soncn.2016.05.005
17. Modenese, A., Korpinen, L., & Gobba, F. (2018). Solar radiation exposure and outdoor work: An underestimated occupational risk. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph15102063
18. Peters, C. E., Pasko, E., Strahlendorf, P., Holness, D. L., & Tenkate, T. (2019). Solar ultraviolet radiation exposure among outdoor workers in three Canadian provinces. *Annals of Work Exposures and Health, 63*(6), 679–688. https://doi.org/10.1093/annweh/wxz044
19. International Commission on Non-Ionizing Radiation Protection. (2010). ICNIRP statement–Protection of workers against ultraviolet radiation. *Health Physics, 99*(1), 66–87. https://doi.org/10.1097/HP.0b013e3181d85908
20. John, S. M., Trakatelli, M., & Ulrich, C. (2016). Non-melanoma skin cancer by solar UV: The neglected occupational threat. *Journal of the European Academy of Dermatology and Venereology, 30*(Suppl 3), 3–4. https://doi.org/10.1111/jdv.13602
21. Ulrich, C., Salavastru, C., Agner, T., Bauer, A., Brans, R., Crepy, M. N., et al. (2016). The European Status Quo in legal recognition and patient-care services of occupational skin cancer. *Journal of the European Academy of Dermatology and Venereology, 30*(Suppl 3), 46–51. https://doi.org/10.1111/jdv.13609
22. Wittlich, M., John, S. M., Tiplica, G. S., Sălăvăstru, C. M., Butacu, A. I., Modenese, A., et al. (2020). Personal solar ultraviolet radiation dosimetry in an occupational setting across Europe. *Journal of the European Academy of Dermatology and Venereology, 34*(8), 1835–1841. https://doi.org/10.1111/jdv.16303
23. Bauer, A., Haufe, E., Heinrich, L., Seidler, A., Schulze, H. J., Elsner, P., et al. (2020). Basal cell carcinoma risk and solar UV exposure in occupationally relevant anatomic sites: Do histological subtype, tumor localization and Fitzpatrick phototype play a role? A population-based case-control study. *Journal of Occupational Medicine and Toxicology, 15*, 28. https://doi.org/10.1186/s12995-020-00279-8
24. Schmitt, J., Haufe, E., Trautmann, F., Schulze, H. J., Elsner, P., Drexler, H., et al. (2018). Is ultraviolet exposure acquired at work

the most important risk factor for cutaneous squamous cell carcinoma? Results of the population-based case-control study FB-181. *British Journal of Dermatology, 178*(2), 462–472. https://doi.org/10.1111/bjd.15906
25. Schmitt, J., Haufe, E., Trautmann, F., Schulze, H. J., Elsner, P., Drexler, H., et al. (2018). Occupational UV-exposure is a major risk factor for basal cell carcinoma: Results of the population-based case-control study FB-181. *Journal of Occupational and Environmental Medicine, 60*(1), 36–43. https://doi.org/10.1097/jom.0000000000001217
26. International Labour Organization. Diagnostic and exposure criteria for occupational diseases. Guidance notes for diagnosis and prevention of the diseases in the ILO List of Occupational Diseases (revised 2010). https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---lab_admin/documents/publication/wcms_836362.pdf (2022). Accessed March 28, 2022.
27. Australia CC: Slip, Slop, Slap, Seek, Slide. https://www.cancer.org.au/cancer-information/causes-and-prevention/sun-safety/campaigns-and-events/slip-slop-slap-seek-slide (1981). Accessed 16 March 2022.
28. Buchanan, L. (2013). Slip, slop, slap, seek, slide - Is the message really getting across? *Dermatology Online Journal, 19*(8), 19258.
29. Affairs FMoLaS: Ordinance on Preventive Occupational Health Care (ArbMedVV). https://www.gesetze-im-internet.de/englisch_arbmedvv/englisch_arbmedvv.html (2019). Accessed December 7, 2022.
30. Alfonso, J. H., Bauer, A., Bensefa-Colas, L., Boman, A., Bubas, M., Constandt, L., et al. (2017). Minimum standards on prevention, diagnosis and treatment of occupational and work-related skin diseases in Europe - Position paper of the COST Action StanDerm (TD 1206). *Journal of the European Academy of Dermatology and Venereology, 31*(Suppl 4), 31–43. https://doi.org/10.1111/jdv.14319
31. International Agency for Research on Cancer of the World Health Organization. (2019). *IARC handbooks of cancer prevention - Preamble for primary prevention*. https://handbooks.iarc.fr/docs/HB-Preamble-Primary-Prevention.pdf. Accessed October 21, 2021.
32. Tenkate, T., & Strahlendorf, P. (2020). *Sun safety at work: A management systems approach to occupational sun safety*. Toronto: Ryerson University.
33. Rocholl, M., Weinert, P., Bielfeldt, S., Laing, S., Wilhelm, K. P., Ulrich, C., et al. (2021). New methods for assessing secondary performance attributes of sunscreens suitable for professional outdoor work. *Journal of Occupational Medicine and Toxicology, 16*(1), 25. https://doi.org/10.1186/s12995-021-00314-2
34. Skudlik, C., Tiplica, G. S., Salavastru, C., & John, S. M. (2017). Instructions for use of the OSD notification forms. *Journal of the European Academy of Dermatology and Venereology, 31*(Suppl 4), 44–46. https://doi.org/10.1111/jdv.14320
35. Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ, 337*, a1655. https://doi.org/10.1136/bmj.a1655
36. Craciun, C., Schüz, N., Lippke, S., & Schwarzer, R. (2012). A mediator model of sunscreen use: A longitudinal analysis of social-cognitive predictors and mediators. *International Journal of Behavioral Medicine, 19*(1), 65–72. https://doi.org/10.1007/s12529-011-9153-x
37. Rocholl, M., Ludewig, M., John, S. M., Bitzer, E. M., & Wilke, A. (2020). Outdoor workers' perceptions of skin cancer risk and attitudes to sun-protective measures: A qualitative study. *Journal of Occupational Health, 62*(1), e12083. https://doi.org/10.1002/1348-9585.12083
38. Ludewig, M., Rocholl, M., John, S. M., & Wilke, A. (2020). Secondary prevention of UV-induced skin cancer: Development and pilot testing of an educational patient counseling approach for individual sun protection as standard procedure of patient care. *International Archives of Occupational and Environmental Health, 93*(6), 765–777. https://doi.org/10.1007/s00420-020-01532-7
39. Ludewig, M., Rocholl, M., John, S. M., & Wilke, A. (2022). Prevention of occupational skin cancer in outdoor workers: Development of a curriculum for multipliers training. *Prävention und Gesundheitsförderung*. https://doi.org/10.1007/s11553-022-00940-6
40. Hoffmann, T., Glasziou, P., Boutron, I., Milne, R., Perera, R., Moher, D., et al. (2016). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ, 348*, g1687.
41. Keurentjes, A. J., Jakasa, I., John, S. M., Ulrich, C., Bekkenk, M. W., Rustemeyer, T., et al. (2020). Tape stripping the stratum corneum for biomarkers of ultraviolet radiation exposure at sub-erythemal dosages: A study in human volunteers. *Biomarkers, 25*(6), 490–497. https://doi.org/10.1080/1354750x.2020.1792551
42. Keurentjes, A. J., Jakasa, I., van Dijk, A., van Putten, E., Brans, R., John, S. M., et al. (2022). Stratum corneum biomarkers after in vivo repeated exposure to sub-erythemal dosages of ultraviolet radiation in unprotected and sunscreen (SPF 50+) protected skin. *Photodermatology, Photoimmunology and Photomedicine, 38*(1), 60–68. https://doi.org/10.1111/phpp.12717
43. Reinau, D., Weiss, M., Meier, C. R., Diepgen, T. L., & Surber, C. (2013). Outdoor workers' sun-related knowledge, attitudes and protective behaviours: A systematic review of cross-sectional and interventional studies. *British Journal of Dermatology, 168*(5), 928–940. https://doi.org/10.1111/bjd.12160
44. Schmalwieser, A. W., Casale, G. R., Colosimo, A., Schmalwieser, S. S., & Siani, A. M. (2021). Review on occupational personal solar UV exposure measurements. *Atmosphere, 12*(2), 142. https://doi.org/10.3390/atmos12020142
45. Carøe, T. K., Ebbehøj, N. E., Wulf, H. C., & Agner, T. (2013). Recognized occupational skin cancer in Denmark – Data from the last ten years. *Acta Dermato Venereologica, 93*(3), 369–371. https://doi.org/10.2340/00015555-1484
46. Wittlich, M., Westerhausen, S., Strehl, B., Schmitz, M., Stöppelmann, W., & Versteeg, H. (2020). Exposition von Beschäftigten gegenüber solarer UV-Strahlung - Ergebnisse des Projekts mit Genesis-UV. https://publikationen.dguv.de/widgets/pdf/download/article/3993. Accessed December 31, 2021.
47. Moldovan, H. R., Wittlich, M., John, S. M., Brans, R., Tiplica, G. S., Salavastru, C., et al. (2020). Exposure to solar UV radiation in outdoor construction workers using personal dosimetry. *Environmental Research, 181*, 108967. https://doi.org/10.1016/j.envres.2019.108967
48. Kovačić, J., Wittlich, M., John, S. M., & Macan, J. (2020). Personal ultraviolet radiation dosimetry and its relationship with environmental data: A longitudinal pilot study in Croatian construction workers. *Journal of Photochemistry and Photobiology B: Biology, 207*, 111866. https://doi.org/10.1016/j.jphotobiol.2020.111866
49. Modenese, A., Gobba, F., Paolucci, V., John, S. M., Sartorelli, P., & Wittlich, M. (2020). Occupational solar UV exposure in construction workers in Italy: Results of a one-month monitoring with personal dosimeters. In *2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe)* (pp. 1–5).
50. Modenese, A., Gobba, F., Paolucci, V., John, S. M., Sartorelli, P., & Wittlich, M. (2020). A one-month monitoring of exposure to solar UV radiation of a group of construction workers in Tuscany. *Energies, 13*(22), 6035.

51. Federal Ministry of Justice and for Consumer Protection. (2019). German "Ordinance on Preventive Occupational Health Care (ArbMedVV)". http://www.gesetze-im-internet.de/englisch_arbmedvv/index.html. Accessed December 31, 2021.
52. World Health Organization. (2021). WHO Website. Classifications. ICD. https://www.who.int/classifications/icd/en/. Accessed December 31, 2021.