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# A narrative review of occupational solar ultraviolet radiation in Britain and skin cancer

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**Background:** Occupational exposure to solar ultraviolet (UV) is known to cause malignant melanoma (MM) and non-melanoma skin cancer (NMSC). However, knowledge of the causal associations has developed erratically.

**Aims:** This review aims to identify when it was accepted that workplace solar UV exposure could cause skin cancer and when it was recognized that there was a risk for outdoor workers in Britain, identifying the steps employers should have taken to protect their workers.

**Methods:** Informative reviews, published since 1974, were located through a systematic literature search. These were used to chart changes in summative knowledge of the role of occupational solar UV exposure in causing skin cancer. An assessment was made of the identified hazards of skin cancer and the recognition of risks for outdoor workers in Britain.

**Results:** From at least 1975, it has been accepted that occupational solar UV exposure could cause squamous cell carcinoma, and from around 2011 for MM and basal cell carcinoma. From 2004, repeated sunburn at work was identified as a likely cause of MM. From 1999, it was accepted that occupational solar UV exposure causes NMSC amongst British workers, and from 2012 there was limited evidence for an MM risk for outdoor workers in northern European countries.

**Conclusions:** Skin cancer risks for British outdoor workers should be actively managed and they should have health surveillance. Outdoor workers who have skin cancer should be eligible for compensation.

## INTRODUCTION

Sunlight comprises a broad spectrum of electromagnetic waves, including ultraviolet (UV) radiation with wavelengths between 100 and 400 nanometres (nm), which is conventionally divided into three bands: UVA (315–400 nm); UVB (280–315 nm) and UVC (100–280 nm) [1]. UV penetrates through the earth's atmosphere, although only a small fraction of the solar UV spectrum penetrates to the ground, most being absorbed or scattered. UV radiation at ground level varies throughout the year and is strongly dependent on latitude, time of day and cloud cover. UVA and UVB bands are damaging to human skin, potentially causing adverse effects, including acute changes such as sunburn (erythema) and long-term chronic effects such as non-melanoma skin cancer (NMSC) and malignant melanoma (MM) skin cancer. UVC does not importantly penetrate to ground level. Recognition that sunlight causes skin cancer has taken time to develop, particularly in higher latitude countries such as Britain where solar UV exposure is intermittent and mostly relatively low. Britain was listed in the bottom 3% of 191 countries for population-level annual ambient erythemal-weighted UV [2].

The three main types of skin cancer, basal cell carcinoma (BCC), squamous cell carcinoma (SCC) and MM, are distinguished by the epidermal cells in which they originate [3]. BCC

is a malignant tumour from basal cells, SCC occurs in keratinocytes, which are the major constituent cells in the epidermis and MM is a cancer of the pigment cells. MM is more likely than NMSC to metastasize, and people with this tumour are more likely to die from their disease than those with NMSC. The risk of all forms of skin cancer from solar UV exposure is strongly dependent on skin colour [4]. Tumours can also be caused by some chemicals and ionizing radiation [3].

By the latter part of the 19th Century, it was known that some outdoor workers suffered from skin cancer, for example, sailor's skin carcinoma (described in 1894 in Germany) and French vineyard workers (1896) [5]. In the 1920s and 1930s, experimental studies on animals provided confirmatory evidence of the relationship between UV exposure and skin cancer. During the early 1970s, the US National Institute for Occupational Safety and Health published a recommended standard for occupational exposure to UV radiation [6]. In the supporting documentation they state, 'The recommended standard ... is based upon action spectra both for erythema and for keratoconjunctivitis and is intended to protect the skin and eyes against acute effects.' They note that '...despite the extensive industrial exposure to ultraviolet radiation, no cases of industrially induced skin cancer or keratosis have been reported.' However, it was concluded that

### Key learning points

#### What is already known about this subject:

- Malignant melanoma (MM) and non-melanoma skin cancer (NMSC) can be caused by occupational solar ultraviolet (UV) exposure, although it was unclear if there was a risk for British workers.
- The dates of knowledge for occupational skin cancer hazards and risks from outdoor work have been unclear, although this information is important for workers seeking compensation for their injuries.

#### What this study adds:

- From at least 1975, it was generally accepted that outdoor solar UV can cause SCC, and from around 2011 BCC and MM.
- From 1999 there is acceptance that outdoor work in Britain may cause NMSC.
- From 2004, repeated UV exposure at work sufficient to cause sunburn was suggested as a risk for MM.

#### What impact this may have on practice or policy:

- Employers in Britain should take skin cancer risks from outdoor work seriously, in line with their legal obligations under the Health and Safety at Work Act.
- Employers in Britain should organize skin health surveillance for outdoor workers and record cases of sunburn caused by outdoor work.

protecting workers from the acute effects of sun exposure would adequately protect them from a possible risk of skin cancer [7]. See Table 2 (available as Supplementary data at *Occupational Medicine* online) for more information about the recommended precautionary measures.

Perhaps because of the generally low and intermittent exposure to solar UV in Britain, the issue of occupational skin cancer has not been given much credibility. For example, the definitive textbook, 'Hunters Diseases of Occupations', which was published in its seventh edition in 1987, has nothing about sun exposure and skin cancer [8]. Notably, there is no European Union Directive or British Regulation that specifically sets out to protect workers from solar UV, although regulations to control exposure to artificial UV radiation were introduced throughout Europe in the 2000s [9].

The introduction of the Health and Safety at Work (HSAW) Act in 1974 in Britain set out the responsibilities of employers and employees to workplace hazards. While there was nothing specific about solar UV exposure or occupational skin cancer, the Act required employers to provide a working environment that was, so far as is reasonably practicable, without risks to the health of their employees. Protecting workers from sunburn should be recognized as part of the responsibilities of employers since sunburn harms health and reduces the quality of life [10]. This defines the minimum legal protection for outdoor workers from solar UV exposure over the last 50 years, i.e. they should be protected from experiencing sunburn.

This is a narrative review of the evolution of evidence for causation of skin cancer by occupational exposure to solar UV in Britain since the introduction of the HSAW, and the steps British employers should have taken to protect their workers. This analysis is relevant to employees seeking compensation for their cancer through the civil courts and it is equally important for employers to understand what protective measures are appropriate today.

## METHODS

Relevant systematic or narrative review articles concerning skin cancer and occupational exposure to solar UV were identified. The scope was restricted to reviews as these were considered to provide a summation of knowledge at the time of publication. Three online bibliographic databases were searched, such as Scopus; EuroPMC and Pubmed. The exact search terms varied depending on the source, but as far as practicable the title, abstract and keywords were searched for the terms: 'skin cancer' and ('ultraviolet' OR 'uv') and ('occupation\*' or 'work\*' or 'job' or 'employ\*') and 'review'; the '\*' represents a wildcard for one or more characters. Papers from 1974 onwards were included. The search results were augmented by additional material from citations within identified articles and other material identified from personal knowledge.

Details of the identified papers were abstracted and combined. The author screened the dataset, first on title and then abstract. Excluded were those articles not written in English, those which only concerned artificial UV, conference abstracts, papers dealing with non-cancer health conditions, e.g. actinic keratosis, papers on ocular melanoma and rare types of skin cancer and papers that only related to specific geographies, e.g. Japanese people, or specific population subsets, e.g. farmworkers or telecommunication workers.

The papers were first assessed as to whether they provided information about the hazard associated with occupational solar UV exposure, either acute or long-term chronic exposure, in terms of potential causation. Then they were evaluated on whether they provided evidence for a risk of skin cancer arising from solar UV exposure in Britain, based on direct evidence from British workplaces or workplaces from similar latitude countries, or the expressed opinion of the authors of the review under consideration.

## RESULTS

It is important to realize that humans may be exposed to the sun at work and during recreational activities and that these exposures may contribute differently to the risk of skin cancers developing. Distinguishing workplace and recreational exposure are important in determining whether solar UV exposure is an occupational carcinogen. Also, exposure to the sun may increase the risk for each of the three main types of skin cancer differently, i.e. the pattern and intensity of exposure may affect the risk. In retrospective epidemiological studies, solar UV exposure has typically been classified based on questionnaire information as: continuous (generally equated with occupational exposure); intermittent (equated

with recreational exposure) or exposure sufficient to cause sunburn [11].

A total of 175 papers were identified from the initial searches, which was reduced to 51 on screening the title and 34 after screening the abstracts. The text of 32 articles was retrieved and on reading a further six papers were identified from the citations. In total, 38 papers were assessed. These papers are listed in Table 1 (Further details on each paper are available as Supplementary data S1 at *Occupational Medicine* online).

Knowledge of the causal links between exposure to solar UV and the risk of skin cancer has not progressed consistently over time. Table 1 summarizes the information from the reviewed papers in terms of the assessed potential for occupational solar UV to cause SCC, BCC or MM (Occupational hazard) and whether a risk for these cancers was identified for British outdoor workers exposed to solar UV (Risk in Britain). The papers prior to 1990 generally identified that solar UV exposure at work could cause all three types of skin cancer or presented equivocal conclusions. In 1992, Osterlind published a review of the epidemiology of MM relevant to Europe [19], which concluded that the risk of MM was associated with intermittent recreational sun exposure causing severe sunburns, particularly in childhood. In this review, it was judged that there was no apparent MM risk linked to occupational exposure.

The first attempt to produce an authoritative systematic assessment of the scientific literature was undertaken in 1992 by the International Agency for Research on Cancer (IARC) [20]. The IARC Working Group classified solar radiation as carcinogenic to humans (a group 1 carcinogen). However, they did not specifically categorize occupational exposure to solar UV as carcinogenic. In 2012, IARC published an updated Monograph that reaffirmed the earlier findings in terms of the carcinogenicity of solar radiation and UV [11]. This report discussed the apparent lack of risk of MM for outdoor workers noting that, 'Outdoor workers tend to be constitutionally protected from solar skin damage and at a lower risk of skin cancer than workers in other occupations because of self-selection based on skin pigmentation.' In summarizing the results of a large meta-analysis of epidemiological studies, the authors reported the risk from sunburn (ever/never) was doubled; for intermittent sun exposure (high/low), the relative risk was 1.6 (95% CI 1.3–2.0), for chronic sun exposure (high/low), the relative risk was 1.0 (95% CI 0.9–1.0) and for total sun exposure (high/low), the relative risk was 1.3 (95% CI 1.0–1.8).

The reviews published from 2012 onwards have concluded that NMSC can be caused by occupational exposure, and three of these five papers also concluded that MM is an occupational hazard from outdoor work in the sun [42,43,47]. One of these papers was an influential review of the association between occupational exposure to UV radiation and the risk of skin cancer by the World Health Organisation [46]. This group carried out a systematic review of the epidemiological literature and a meta-analysis in support of international efforts to estimate the global burden of work-related disease. However, the authors overall concluded that there was 'inadequate evidence for harmfulness' for MM mortality and NMSC mortality, but for MM incidence there was 'limited evidence for harmfulness' and for NMSC incidence there was 'sufficient evidence of harmfulness'.

In terms of a skin cancer risk for outdoor workers in Britain, the evidence summarized in Table 1 shows that prior to 1999 there was no explicit suggestion of any risk. In that year, Coggon [26] wrote that, in his opinion occupational exposure to solar UV may cause several hundred cases of NMSC each year although such exposure was unlikely to be a major cause of MM. From around 2010 onwards, there seems to be a general view that outdoor work in Britain causes NMSC (despite some uncertainty about the causal role of outdoor work in BCC), and in 2012, Young and colleagues estimated that in Britain around 1500 cases of NMSC and 13 deaths from these diseases could be attributed to outdoor work [42]. These authors did not estimate a risk for MM from occupational UV exposure.

Only one of the reviews included in the present paper suggests a possible risk for MM from workplace exposures in Britain [43]. This was a comprehensive review of the epidemiological literature on the topic where 10 good quality studies explored the relationship between occupational UV exposure and MM with six of these studies showing outdoor occupational UV exposure was significantly associated with MM incidence (from Norway, Sweden, Italy (three) and Australia, with the European countries having similar latitudes to Britain). Gawkrödger [3], in 2004, in his review of the occupational health aspects of skin cancer noted that outdoor workers who repeatedly experienced severe sunburn could be at risk of MM; Young later repeated the warning [36]. It is only these two papers that clearly suggest a MM risk for British outdoor workers.

The HSE leaflet, 'Sun protection advice for employers of outdoor workers' (INDG337) was published in 2001 [48], although earlier versions may have been produced to coincide with the government public health 'Sun Awareness' campaigns [49], i.e. first around 1998. The 2001 version of the leaflet clearly states, 'UV radiation should be considered an occupational hazard for people who work outdoors', although it only provides, 'notes on good practice which are not compulsory but which you may find helpful in considering what you need to do', see Table 2 (available as Supplementary data at *Occupational Medicine* online).

## DISCUSSION

This narrative review was based on a search of the published literature for review articles on the topic. While this approach may have missed some individual papers, it is considered a pragmatic approach to identify the commonly held knowledge of the hazards and risks of workplace solar UV exposure. The information covers the last 50 years and does not attempt to explore the longer term development of knowledge of skin cancer risks for outdoor workers. However, opinions about the hazards of occupational solar UV exposure changed as the epidemiological knowledge accumulated. In retrospective epidemiological studies, distinguishing between occupational and recreational exposure is difficult and this has been a key issue over the last 50 years. The issue is further complicated by the effect of skin colour in mediating the risk of skin cancer and the variation in solar UV exposure by latitude. There is no real dispute that most cases of skin cancer are caused by solar UV exposure (certainly since the IARC Monograph of 1992), but the important issue is to what extent workplace exposure is implicated. Researchers

**Table 1.** Summary information about the hazard and risk of occupational solar UV exposure

Publication date	Occupational hazard			Risk in Britain			Citation
	SCC	BCC	MM	SCC	BCC	MM	
1975	+	+	+				[12]
1979	+	+	+				[13]
1980			?			-	[14]
1987			?			?	[15]
1989	?	?					[16]
1989	+	+					[17]
1992			?			-	[18]
1992			-			-	[19]
1992	?	?	?				[20]
1994	?	?	?				[21]
1996	+	+	+	-	-	-	[22]
1997			-			?	[23]
1997	+	-	-				[24]
1997		+					[25]
1999	+	+	?	+	+	-	[26]
1999	+	?	?				[27]
2001	+	-	-				[28]
2003		-					[29]
2004	?	?	★			★	[3]
2005		-					[30]
2005	?	?	?				[31]
2005			-				[32]
2007	+	+	+				[33]
2007	+	+	+	-	-	-	[34]
2008			?				[35]
2009	+	?	★	?	?	★	[36]
2010	+			+			[37]
2010	+	-		+	-		[38]
2011	+			+			[39]
2011		+			+		[40]
2012	?	?	?				[11]
2012	+	+		+	+		[41]
2012	+	+	+	+	+	-	[42]
2015			+			?	[43]
2017	?						[44]
2018	+	+	-				[45]
2021	+	+	?				[46]
2022	+	+	+				[47]

+, occupational hazard or risk identified; -, no hazard identified, or no risk identified for British workers; ★, sunburn at work identified as a hazard or risk and ?, uncertain conclusion.

in the 1970s appeared to have assumed that because outdoor workers were exposed to solar UV, there was a hazard for these individuals. However, during the 1980s and early 1990s, there was a greater degree of scepticism about the role of occupational UV exposure in causing skin cancer, primarily because the risk, particularly for MM, was seen as linked to intermittent recreational exposure and instances of sunburn.

The evidence for occupational solar UV exposure causing SCC has been most consistent over time, with 19 of the 26 informative reviews positively identifying a risk. The attribution of an occupational hazard for BCC has been less consistent (14 positive, 5 negative and 8 uncertain or uninformative). An occupational cause for MM has similarly been unclear (10 positive—2 of which focussed on sunburn at work, 6 negative and 11 uninformative or uncertain). However, on balance, from around 2011, the evidence becomes more settled that occupational UV exposure can cause BCC and MM. Although, the authoritative WHO review from 2021 [46] concluded there was insufficient evidence to unequivocally conclude, there is an occupational hazard of MM from occupational UV exposure.

In 2004 and 2009, there were suggestions that because the risk of MM was linked to episodes of sunburn throughout life, those workers who experienced sunburn at work could also be at risk. Under the HSAW Act, there was an obligation on employers from 1974 to protect their workers from sunburn from exposure at work. Sunburn is a minor transient ailment, so it could be argued that the effort required by employers to comply with the law should have been proportionate and might just have involved training and support to employees to protect themselves. However, the recognition that repeated episodes of sunburn at work are a risk for MM, a possibly fatal disease, should, require more rigorous and strictly applied protective measures. This has not been done in most British workplaces. The HSE advice to employers on sun protection has been non-binding.

The reviews discussed in this paper do not account for the ambient UV at the locations where the studies were undertaken. While they are informative about the hazards linked to outdoor work, they do not necessarily indicate that there is a risk in a specific country. Outdoor UV irradiance is generally low in Britain and so the assessment of the risk is dependent on a more considered interpretation of the epidemiological evidence. From 1999 onwards, it is generally held that NMSC could be caused by outdoor work in Britain. However, it is uncertain whether, other than from repeated episodes of sunburn, occupational exposure to solar UV in Britain can cause MM.

Workers seeking compensation for ill health caused by work must either sue in the civil courts for negligence on the employer's part or apply for no-fault Industrial Injuries Disablement Benefit (IIDB). Unfortunately, neither MM nor NMSC are prescribed industrial diseases within IIDB, so benefit is unavailable. The main problem has been the lack of acceptance that these diseases can be caused by occupational exposure to solar UV in Britain [50]. However, we have previously argued that the risk of NMSC could be doubled after around 20–30 years of outdoor work in Britain [51]. Also, repeated episodes of sunburn over many years may double the risk of MM, particularly among workers employed in higher latitude countries [32]. There is, therefore, a prima facie case for prescription, and possible civil compensation for negligent exposure, for both MM and NMSC.

What should British employers have done? From 1974 to 2000, employers should have taken steps to protect workers from sunburn. This could have mainly been advisory and supportive, proportionate to the severity of the hazard. At this time, employees should likely have had the main obligation to comply with the necessary actions, but employers should have

provided support through education and training and required wearing clothing that covered the skin along with the use of sun protection creams. From 2001 onwards, there was an onus on employers to follow the HSE Code and to implement strict sun safety provisions because of the identified skin cancer risk for outdoor workers in Britain. Not following the code could have resulted in employers being in breach of their statutory obligations under the HSAW Act, although as described above the official advice from HSE is weak. Employers should have adapted outdoor work to help minimize UV exposure and where this was not possible to adequately control the risk using appropriate personal protective clothing and sunscreen. They should have also provided education about skin health surveillance. However, from 2004 onwards, employers should have recognized the serious MM risk for British outdoor workers who experienced sunburn. In addition to the above provisions, employers should have proactively managed outdoor work to minimize the risk of sunburn, including supervision of workers to ensure compliance with mitigation measures. Employers should have organized skin health surveillance and had systems for recording of cases of sunburn at work. However, there is no evidence that these things are widely done in British workplaces. The HSE, employers and employee organizations in Britain must take the skin cancer risks from solar UV exposure more seriously than in the past.

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### COMPETING INTERESTS

J.C. is a member of the Industrial Injuries Advisory Council and he occasionally undertakes medico-legal consultancy, some of which involves occupational skin cancer claims.

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