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ORIGINAL ARTICLE

Questionnaire-based evaluation of occupational and non-occupational solar radiation exposure in a sample of Italian patients treated for actinic keratosis and other non-melanoma skin cancers

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Abstract

Background An adequate evaluation of the ultraviolet (UV) cumulative exposure is a major problem in epidemiological studies on chronic skin damage. Questionnaires may be applied as useful tools.

Objective We developed an original questionnaire to evaluate individual cumulative exposure to solar radiation (SR) in patients affected by actinic keratosis (AK), basal cell carcinoma (BCC) and squamous cell carcinoma (SCC).

Method The questionnaire, considering both working and leisure exposure, was applied to evaluate the whole life history of solar UV radiation exposure in a group of patients of the Dermatologic Clinic of UNIMORE.

Results In outdoor workers (OW), the co-presence of AK/*in situ* SCC and invasive non-melanoma skin cancers (NMSCs) was increased compared to indoor workers (IW), as was the frequency of multiple skin lesions. The prevalence of skin lesions of the face was significantly higher in OW. Work 'sometimes' or 'often' in the shades was associated with an absence of skin lesions on the shoulders and neck, while workers adopting 'sometimes' or 'often' a downward bent position were more likely to develop lesions on the top of the head. Considering leisure activities, the use of tanning beds was associated to the presence of skin lesions on the shoulders, neck and chest. Considering vacation periods, subjects spending at least 2 h outdoor in the period 11 am to 1 pm presented earlier diagnoses of skin cancers.

Conclusion Results of the original questionnaire developed are coherent with current knowledge and confirm the important role of UV exposure, both occupational and recreational, in the development of AK and NMSCs. Data support the hypothesis that this questionnaire can be applied as useful tool for the evaluation of cumulative UV exposure in future epidemiological studies.

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Pilot investigation in accordance with all national regulations and with principles of the Declaration of Helsinki

Introduction

Long-term solar radiation (SR) exposure is associated with various skin diseases like photoageing, actinic keratosis (AK), basal cell carcinoma (BCC), squamous cell carcinoma (SCC) and malignant melanoma (MM). SR as well as ultraviolet radiation (UVR) are carcinogens (class 1 IARC).[1] The sun represents the main UVR source of exposure for humans, but the spectral composition of SR on the earth's surface is quite different from that emitted by the sun: most part of UV (all wavelengths of less than 290 nm) are filtered by the atmosphere. Consequently, less than 5% of SR on the earth is composed by UV (essentially UV-A), while infrared and visible radiation constitute, respectively, the 45% and about the 50% of the spectrum.[2–4] The quantity and the spectral composition of SR reaching the earth's surface can vary depending on different factors as the elevation angle of the sun above the horizon, the meteorological conditions (clouds,

rain, snow, etc.), atmospheric pollutants and type of incident surfaces (e.g. fresh snow reflects up to 90% of UVR)[3–6] In addition, several individual factors are also involved in the modulation of SR exposure. Occupational activity is considered among relevant factors. The European Agency for Safety and Health at Work estimates that UVR is a carcinogen in 36 employment sectors of the European Union (in 11 sectors it ranks first among the other carcinogens)[7] and that about 14.5 million outdoor workers (OR) are exposed to SR for at least 75% of their working time. An adequate adoption of protective equipment and individual protecting behaviours (e.g. regular use of covering clothes, hats, sunscreens, the habits to stay in the shades and to interrupt the exposure in the central hours, etc.) are crucial to reduce SR exposure, both during work and leisure activities.[8–11] Finally, among the most important factors influencing the skin risk related to SR exposure, there are individual characteristics, both genotypic and phenotypic, e.g. Fitzpatrick's fair phototypes.[12] Although the knowledge on the diagnosis and treatment of the above-mentioned skin cancers has made great strides in recent years,[13–18] to date, an important aspect which is still incomplete is the development of an adequate dose–effect relationship, i.e. threshold levels for UVR exposure which increase the risk for cancer induction. The vast majority of the studies considered in the 2012 IARC monograph evaluate cumulative UV skin exposure with clinical parameters (that are actually an expression of damage) like solar lentigo and AK itself. Possible tools to evaluate individual sun exposure are questionnaires, but to date, only in few studies, quantitative or detailed semiquantitative questionnaires were applied. Also individual UV dosimeters are useful, but data are limited, and meters cannot be used for a large-scale monitoring of UV exposure of populations throughout years.[4] According to IARC, BCC shows significant positive associations with sunburns at some stage of life or overall and the presence of AK (which is the strongest risk factor). For SCC, there is currently no accordance on the role of sunburns, and also in this case, the presence of AK is the strongest risk factor identified.[4] Regarding MM, the results of one of the biggest meta-analyses published in 2005 show a strong correlation with the presence of actinic tumours, sunburns and intermittent sun exposure, a low association with 'total sun exposure' and no association with 'chronic sun exposure'.[19] The IARC Working Group noted that the omission from many studies of the lentigo maligna melanoma potentially results in an underestimation of the SR exposure association with MM of head and limbs.[4] Regarding sunburns, we should consider them an event occurring typically during leisure exposures, and especially on summer holidays, when very short and intense exposures are possible. We could also assume that cumulative SR exposure if perpetrated for several years is typical of OW. Two recent meta-analysis on occupational UVR exposure investigated, respectively, the association with BCC[20] and with SCC.[21] The conclusions were that OW have a significant increased risk for both, with an odds ratio (OR) of 1.4 (confidence intervals – CI: 1.23–1.66) for BCC, based on 23 studies, and with an OR of 1.8 (CI: 1.4–2.2) for SCC, based on 18 studies. According to these findings, in some countries, e.g. Germany, NMSC are recognized as occupational diseases if specific criteria are respected; in particular, a minimum number of years worked outdoors is needed to assume an occupational aetiology.[22,23] Considering specifically the construction sector, in the multicenter European study HELIOS, an OR for epithelial skin cancers of 1.10 was observed, while in agriculture and fisheries sectors, the OR was 1.18.[24] Despite these results, in a 2013 case–control study conducted in Eastern Europe on about 600 NMSC patients and 500 controls, Surdu *et al.* found for OW an unexpected protective effect of occupational exposure to natural UVR limited to light skinned.[25] Also in a 2009 retrospective study from Northern Europe analysing the period 1961–2005, a standardized incidence ratio (SIR) was calculated for SCC in various outdoor activities and it was found that the incidence was significantly lower than the expected for farmers and fishermen.[26] One of the most likely causes for these unexpected results is the exposure evaluation: it is possible that the use of the rough label 'indoor workers' (IW) vs. 'OW' is not adequately representative of the real individual exposure for epidemiological studies. An adequate attention to exposure habits and type of occupational and leisure activities is necessary for a more realistic estimation of the cumulative UVR received by the skin in a period of several years, to correlate chronic skin damage with individual SR exposure. A possibility for a comprehensive evaluation of individual exposure are questionnaires that can take into consideration, and evaluate the relevant factors and characteristics known to be involved in the determination of occupational and non-occupational SR exposure.[27] We report here the results of the application of such a questionnaire in a sample of dermatologic patients.

Methods

From January 2014 to August 2015, we recruited a total of 58 dermatologic patients who underwent a session of photodynamic therapy for the presence of cancers (AK, BCC and/or SCC) due to a severe actinic skin damage at the Department of Dermatology of the University of Modena and Reggio Emilia. The study was conducted in accordance with all national regulations and with principles of the Declaration of Helsinki. Complete information regarding the study was given, and subjects were informed that participation was voluntary, and that they were free to withdraw from the study at any time. Written informed consent was collected. Nobody refused to participate or withdrew during the study. A trained medical student and a resident physician of the specialization school in Occupational Medicine (AA and AM) administered an *ad hoc* questionnaire (the questionnaire, and the method, have been described and discussed in a previous paper[27]). The questionnaire takes

15–40 min to complete; administration was performed in the period after the topic application of the 5-ALA or ALA methyl ester on the lesions, while patients were waiting for the LED treatment.

The questionnaire is composed of three sections: one specifically referred to working exposure of OW, another to leisure exposure not during vacation and a last one to vacation periods. Each section is composed of 12 items investigating the type of outdoor activity, the total time people spend outside during the activity and the exposure to SR during the period 11 am to 3 pm, and main personal habits that may influence SR exposure. All collected data are referred to the period of the year March–October, except for vacations in the snow: in this case, the whole year was considered. At the beginning of each section, the interviewer has to define the period of life, in number of years, the section refers to; a new form of a section was administered in case of any significant change in exposure habits likely to influence SR exposure, primarily outdoor job change, workplace change, change of residence or vacation moving to a place with a different UV index, change in the number of vacation days per year, starting of a new outdoor hobby/sport, etc.

The following excluding criteria were applied: an inadequate ability to understand the Italian language, an age <40 years old and a length of employment of less than 10 years.

Data were analysed using the software SPSS version 21 for Windows: statistical analyses performed included Student's *t*-test, Chi-square test, Pearson's correlation *r*.

Results

Fifty-eight questionnaires were collected in mainly male patients (81%) aged 43–91 years (mean age = 70.8 ± SD 11 years). With regard to occupation, the majority of the patients (57%) referred an outdoor activity as the main profession in their life. The most frequent outdoor jobs were agriculture (21% of the subjects) and construction (14%).

No significant differences were observed between OW and IW for the main examined demographic and pathologic characteristics: age, sex, smoke habits, alcohol consumption, diabetes, etc. OW did not report any adequate use of protective equipment to protect themselves from sunlight during the occupational activities: 15.2% of OW never wore protective clothing, 90% never used sunscreens at work, 39% never wore a brimmed hat and 60.6% never used protective sunglasses. The frequencies of skin diseases are described in Table 1. As expected, AK was the most frequent, detected in 57.0% of the patients: 29.3% presented only AK, 13.8% AK and BCC, 10.3% AK and SCC. Comparing OW vs. IW, we found a higher rate of AK alone in IW (respectively 19% vs. 10.3%), but the frequency of multiple pathologies (AK in association with BCC or SCC) was increased in OW: respectively 10.3% vs. 0% for AK + BCC and 10.3% vs. 3.4% for AK + SCC, even if the differences were not significant at the chi-square test, possibly related to the relatively small number of subjects included in the study. Regarding the number of skin lesions, 14.3% of the patients had a single lesion, while the majority of the sample had 2–10 lesions, and only 3.6% of the subjects had more than 20 lesions. In OW group, the percentage of subjects with 11–15 skin lesions and with 16–20 lesions was higher than in IW group (7.1% vs. 3.6% and 5.4% vs. 0% respectively), even in this case also the chi-square test was not significant (Table 1).

Table 1 Frequencies of skin diseases and number of skin lesions in 58 dermatologic patients (33 OW and 25 IW) who completed the interviewer-administrated questionnaire on SR exposure

	% in OW	% in IW	% in total sample
Skin diseases			
AK	10.3	19	29.3
AK + BCC	10.3	3.4	13.8
AK + SCC	10.3	0	10.3
AK + MM	3.4	0	3.4
BCC	8.6	10.3	19
SCC	6.9	3.4	10.3
BCC + SCC	1.7	1.7	3.4
BCC + MM	0	1.7	1.7
Others	5.1	3.4	8.6
Number of skin lesions			
1	7.1	7.1	14.3
2–5	16.1	17.9	33.9
6–10	17.9	14.3	32.1
11–15	7.1	3.6	10.7
16–20	5.4	0	5.4

Considering the localization of skin lesions, Table 2 shows the results of the analyses of the associations between type of occupational activities and localization of the skin lesions. OW were more likely to present lesions on the back and on the arms compared to IW and we have found more lesions on the shoulder, neck and chest of IW but the differences for these localizations were not significant. For legs and on the top of the head, the number of lesion was similar in the two groups. Lesions of the face were more frequent in the OW group with a significant chi-square value of 8.124 (Table 2).

Analysing protective habits during work activities, we found a statistically significant association between the absence of skin lesions in the shoulder and neck region and the habit to work 'sometimes' or 'often' in the shades (Table 3).

Regarding working postures of OW, chi-square test showed that workers who adopted 'sometimes' or 'often' a bent-downward position were more likely to have skin lesions on the top of the head (Table 4).

Lastly, we performed a Pearson's correlation *r* to investigate the type of associations between the age at the first diagnosis of skin diseases (dependent variable) and the total number of years spent as OW (independent variable). The *r* coefficient (0.44) was positive and significant indicating a direct proportionality.

Table 2 Localization of skin lesions in 58 dermatologic patients (33 OW and 25 IW) who completed the interviewer-administrated questionnaire on SR exposure

Localization of skin lesion	% in OW	% in IW	Chi-square	% in total sample
Top of the head	21.4	21.4	n.s.	42.9
Face	42.9	17.9	8.124 ($P < 0.01$)	60.7
Arms	16.1	7.1	n.s.	23.2
Shoulders/neck	3.6	7.1	n.s.	10.7
Chest	1.8	7.1	n.s.	8.9
Legs	7.1	7.1	n.s.	14.3

Table 3 Skin lesions of the shoulder/neck and habit to work in shades

	Working in shades		
	Never/seldom (%)	Sometimes/often (%)	Chi-square
Shoulders/neck lesions			
Yes	6.5	0	8.908 ($P < 0.05$)
No	12.9	80.6	

Table 4 Working posture 'bent-downward' and skin lesions on the top of the head

	Working posture 'bent-downward'		Chi-square (significance)
	Never/seldom (%)	Sometimes/often (%)	
Lesions at the top of the head			
Yes	12.9	25.8	4.918 ($P < 0.05$)
No	45.2	16.1	

Shifting now to the analyses of leisure time activities, our data showed a significant association between the frequency of leisure exposure to artificial UV sources (tanning beds) and the presence of skin lesions in the region of the shoulders/neck and chest, with chi-square score of, respectively, 17.203 and 22.713 (Table 5).

With regard to vacation periods in summer season, the subjects who spent at least 2 h outdoor between 11 am and 3 pm revealed a lower age at the first diagnosis of skin diseases: in fact, the mean age at the first diagnosis of the skin diseases was significantly lower compared to subjects who avoided the exposure or who were exposed 1 h or less in the same period of the day. In the same group also the total number of skin lesions was higher (8 vs. 6.5), but in this case, the difference was not significant (Table 6).

Discussion and conclusion

The association between solar UVR exposure and NMSCs has been observed in a large number of studies; however, an assessment of cumulative SR, which includes recreational and working exposure, is a difficult process, involving a lot of variables, and it is performed only in few studies. In our research, we adopted an *ad hoc* specific interviewer-administrated survey to evaluate cumulative exposure to SR of a group of patients affected by AK, BCC and SCC. This pilot study has some limitations. The first one being a relatively low sample size; secondly, to date, we have collected only subjective qualitative exposure data. In a development of this study, we intend to enlarge the sample, and to associate the subjective evaluation of exposure with objective measurements of SR exposure, including individual dosimetry and environmental data on UV radiation, e.g. meteorological data from specific databases, for retrospective exposure evaluation.

On the other hand, our study also has significant strengths: the questionnaire adopted is detailed, specific and it takes into account the most important factors modulating both occupational and non-occupational exposure, providing a comprehensive subjective evaluation of cumulative SR received by the subjects.

Considering OW activities, the most represented category in our sample was agriculture. This finding may correlate with the

Table 5 Use of UV sunbeds and lesions of the shoulders/neck and chest.

	Lesions of the shoulders/neck		Chi-square	Lesions of the chest		Chi-square
	Yes (%)	No (%)		Yes (%)	No (%)	
Exposure to UV sunbeds						
Never	7.3	81.8	17.203 ($P < 0.0001$)	3.6	85.5	22.713 ($P < 0.0001$)
Sometimes	0	7.3		1.8	5.5	
Often	3.6	0		3.6	0	

Table 6 Age at the first diagnosis of the skin disease and total number of skin lesions vs. number of hours spent outdoor between 11 am and 3 pm during summer holidays

	Hours spent outdoor between 11 am and 3 pm		
	0–1	2–4	*P*
Age at the first diagnosis of the skin disease	66.0	52.6	0.001
Total number of skin lesions	6.5	8.0	n.s.

advanced average age of our patients: at the time of the questionnaire administration, the large majority of the patients were retired and they had been employed in agriculture as their main occupational activity during their lives. The second OW category in frequency is construction sector. According to recent publications, relevant SR exposures have been registered among construction workers and farmers. Regarding the former category, studies show a SR exposure of 9.9 standard erythemal dose (SED) in Australia,[28] a daily dose ranging from 11.9 to 28.6 SED depending on the altitude in Switzerland[29] and a SED of 6.11 in Spain.[30] For farmers, high exposure to UVR has been reported in New Zealand,[31] Australia,[32] Austria[33] and Italy, where 1870 Joule/m^2 was measured in April.[34] In all these studies, the researchers measured an acute exposure to SR in a single day or few days with personal dosimeters. On the other hand, very few studies attempted to retrace the history of a chronic exposure to SR in groups of OW.[35,36] Regarding adverse skin effects, in the recent meta-analysis on UVR occupational exposure of Bauer *et al.* (2011)[20], a significantly increased OR of about 1.5 with respect to IW was found for BCC, while Schmitt and *et al.* (2011)[21] reported an almost doubling of the OR of developing SCC. Our data are in agreement with these results: we found two relevant differences between OW and IW, even if they were not statistically significant. The simultaneous presence of both, *in situ* (AK) and invasive NMSCs (SCC and BCC) was more frequent among OW, and on the other hand, the proportion of subjects with an higher number of skin lesions (>10) was elevated in OW. As regards the localization of skin lesions on patients' bodies in the OW subgroup, we found a significantly higher prevalence of skin diseases of the face in OW than in IW. This finding is consistent with a rare use of face protections (e.g. hats, protective sunglasses, sunscreens) in OW. Similar data have also been reported in a study of nine construction workers, who have developed NMSCs mainly in various areas of the face, such as cheeks, nose and forehead.[37] Protective behaviours in OW seem to be relevant in the development of skin diseases: our data show that there was a significant association between the absence of skin lesions of the shoulders and neck and the habit to work 'sometimes' or 'often' in the shade. Globally, there was a scanty use of personal protective equipment among OW: for example, 90.9% never used sunscreens, 60.6% never wore protective sunglasses and 39.4% never wore a brimmed hat at work. Similar data were also collected in a 2013 Italian study that demonstrated that 36% of OW did not use hat and 60% did not wear sunglasses.[38] Also, working postures are important: we found a higher prevalence of skin lesions of the top of the head in OW who referred to work frequently in a bent-downward position, according to the findings of Milon *et al.* in a group of construction workers, where UV measurements with personal dosimeters were influenced by the posture and the orientation of the body in the sun.[29] Concluding the discussion regarding OW, our data suggest also a result consistent with the findings of the studies by Surdu and Pukkala research groups, who found a protective effect of OW for NMSCs 25–26: we found a positive correlation between the total number of years spent as OW and the average age of onset of skin diseases. This result may be due to a sort of adaptation mechanism (tanning, thickening of the skin, etc.) in OW chronically exposed to SR, but it can be also due to a reduced tendency of OW to undergo dermatological examinations. Another possibility is a 'healthy worker effect', in fact a selection related to avoidance/leaving the outdoor job of fair skinned individuals cannot be excluded in our sample.

In addition to occupational exposure, we evaluated recreational exposure in the sample of dermatologic patients, both weekend exposure and vacation exposure to SR. Our data confirm the relevancy of tanning beds, according to a 2006 systematic review performed by IARC working group, who found an increased relative risk for SCC in three different epidemiological studies (and of course an increased RR also for melanoma), but not for BCC.[39] We found an association between use of tanning beds and presence of *in situ* and invasive NMSCs of the shoulders, neck and chest: the localization of skin lesions may be consistent with the fact that these body areas are usually paler and less exposed to solar UVR than other areas like face and arms.

Finally, with regard to vacations, we did not find any significant exposure in winter in the snow. So, our data refers to summer holidays at the seaside. We found that patients who claimed to usually spend at least 2 h outdoor between 11 am and 3 pm during their vacations had a lower age of onset of skin diseases than the other patients. The habit to have intense sunbaths in summer is quite common, especially among younger people from northern countries, often with fair phototypes. In a recent study conducted on a group of Irish people having holidays in Mediterranean locations, 44% of the subjects were likely to burn their skin, 64% planned to sunbathe between 11 am and 3 pm and only less than 25% of the subjects spent <5 h/day in the sun. Regarding protective habits, only 40% apply sunscreens with a protection factor >15.[40] Also, in our sample of dermatologic patients affected by AK, SCC and BCC the use of personal protective equipment was scanty during leisure time in weekend and in vacation, with percentages of adoption of protections comparable to that of OW.

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