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2 **Skin cancer in outdoor workers exposed to solar radiation:**
3 **a largely underreported occupational disease in Italy**

4 **F. Gobba,¹ A. Modenese,^{1,*} S.M. John²**

5 ¹Department of Biomedical, Metabolic and Neural Sciences, Chair of Occupational Medicine, University of Modena & Reggio Emilia,
6 Modena, Italy

7 ²Department of Dermatology, Environmental Medicine, Health Theory, Institute for Interdisciplinary Dermatological Prevention and
8 Rehabilitation (iDerm), Lower-Saxonian Institute of Occupational Dermatology (NIB), University of Osnabrueck, Osnabrueck, Germany

9 *Correspondence: A. Modenese. E-mails: alberto.modenese@unimore.it; albertomodenese1@gmail.com.

10 **Abstract**

11 **Background** Solar UV radiation (sUVR) is one of the main carcinogen exposures in occupational settings, and UV-
12 induced skin cancers are the most frequent tumours in fair-skinned individuals worldwide.

13 **Objectives** According to this premise, we should expect a high number of occupational skin cancers reported to the
14 national workers' compensation authorities each year, also considering that the incidence of skin cancers has been constan-
15 tly increased in recent years

16 **Methods** We examined the data on reported non-melanoma skin cancers (NMSC) and actinic keratoses (AK) to the
17 Italian National Workers Compensation Authority (INAIL) from 2012 to 2017, and we compared the number of reported
18 skin cancers for outdoor workers with the expected numbers, obtained from currently available NMSC incidence rates
19 for the Italian population applied to the occupational sUVR-exposed workers estimated with the CAREX methodology in
20 Italy in 2005.

21 **Results** The cases of NMSC reported each year to INAIL in Italy are 34 per year on average, while for AK the mean
22 number of reported cases is of only 15/year. We estimated a number of expected NMSC cases in Italy for solar UV-ex-
23 posed workers ranging between 432 and 983, representing a proportion between reported vs. expected skin cancers of
24 only 3.5–6.2%.

25 **Conclusions** Our study clearly shows that occupational skin cancers in Italy are largely underreported, and, accord-
26 ingly, urgent initiatives should be taken to raise appropriate awareness to the problem of occupational sUVR-induced
27 skin cancers, so that adequate preventive measures can be implemented rapidly.

28 **Keywords:** solar UV radiation, outdoor work, occupational skin cancer, occupational disease, non-melanoma skin cancer, keratinocytes
29 carcinoma.

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31 **Conflict of interest**

32 The authors declare no conflicts of interest

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35 **Introduction**

36 Solar radiation exposure, mainly related to the ultraviolet (UV)
37 component, is one of the most widespread occupational risks in
38 Italy: according to the CAREX database, workers regularly
39 exposed to solar UV radiation (sUVR) for more than the 75% of
40 their working day are more than 700 000.¹ Nevertheless, this
41 evaluation possibly underestimates the real number of the
42 sUVR-exposed workers, as various studies suggest that a large
43 part of workers engaged, e.g. in agriculture and forestry, fishing,

44 construction and mining (more than 2 500 000 in Italy) are
45 exposed to sUVR levels largely exceeding the threshold limits^{2,3}
46 valid for both natural and artificial UVR proposed by the Ameri-
47 can Conference of Governmental Industrial Hygienists
48 (ACGIH),⁴ while the International Commission on Non-Ioniz-
49 ing Radiation Protection (ICNIRP)⁵ proposes the same limits
50 only for artificial UVR exposure.

51 Solar UVR can induce several adverse health effects in out-
52 door workers, mainly to the eye^{3,5,6} and the skin, including skin

cancers:^{7–9} solar radiation and UV are both classified among Group 1 carcinogens by the International Agency for Research on Cancer (IARC).⁷ In outdoor workers, the most relevant types of skin cancers related causally almost exclusively to sUVR exposure are basal cell carcinoma (BCC, [ICD11: 2C32]) and squamous cell carcinoma (SCC, [ICD11: 2C31], including actinic keratosis as *in situ* SCC [Actinic intraepidermal squamous cell carcinoma; ICD11: 2E64.01]).^{10,11} These cancers are also the most frequent cancers in Caucasians in the general population;¹² they are still most frequently referred to as -melanoma skin cancers (NMSC), even though, more recently, the more exact term keratinocyte carcinoma was suggested.¹³ Cutaneous malignant melanoma (MM) is also believed to be correlated with UVR exposure, but in particular with intermittent UVR exposure, especially in early life, rather than with cumulative exposure, and the causal relation with occupational sUVR is considered less conclusive.¹⁴ Nevertheless, it has to be noted that recent studies suggest a possible association also for specific subtypes of MM, such as lentigo maligna melanoma (LMM), with chronic lifetime sun damage, while cumulative UV exposure in some studies is claimed not to be a significant risk factor for superficial spreading melanoma (SSM) and nodular melanoma (NM).¹⁵

A problem of NMSC in epidemiology is that, for various reasons, cancer registries worldwide often do not include data on these cancers, or the quality of data is controversial and data are frequently incomplete and/or cancers are underreported, resulting in a vast underestimation of their real incidence.¹⁶ In order to deal with this issue, recently, in Europe it has been proposed that in Cancer Registries agendas a special focus on cancers caused by identifiable risk factors that are amenable to preventive actions, e.g. occupational exposures and ultraviolet-related skin cancers, should be considered.¹⁷

According to data provided by the Italian Association of Medical Oncology (Associazione Italiana di Oncologia Medica – AIOM), the Italian Association of Cancer Registries (Associazione Italiana dei Registri Tumori – AIRTUM) and the Italian National Institute of Health (Istituto Superiore di Sanità – ISS), in 2018 the expected new cases of BCC and SCC in Italy were, respectively, 64 000 and 19 000.¹⁸ In another study, performed in Trentino region, Northern Italy, Boi *et al.* calculated a standardized annual incidence of 61.5 per 100 000 (CI 58.5–64.5) for BCC and of 16.3 per 100 000 (CI 14.9–17.7) for SCC,¹⁹ but it has also to be considered that, in Northern Italy, the prevalence of NMSC is lower than in the south, and that, according to some studies, the incidence of these cancers is constantly increasing.^{20,21}

Epidemiologically, the causal relation between occupational sUVR exposure and NMSC is now firmly established,^{10,11,22–24} however, only a few European countries recognize these cancers as occupational diseases.^{12,22} In Italy, NMSC, and also actinic keratosis (AK), are included in the list of occupational diseases that can be compensated in workers exposed to UVR and to sUVR by the Italian Workers' Compensation Authority (Istituto

Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro – INAIL), while MM is not included in that list.²⁵ Furthermore, according to the Italian legislation, the reporting of NMSC, and AK, in exposed workers is legally required.²⁶ Considering the above-mentioned high incidence of NMSC, and the large number of workers exposed to sUVR, we should expect that these cancers are among the most frequent occupational cancers reported to INAIL.

We decided to test this hypothesis. Accordingly, we estimated the number of occupational NMSC expected in Italian workers according to the prevalence in the general population and the number of outdoor workers provided with the CAREX data for Italy,¹ and we compared these estimates with the number of cases of sUVR-induced occupational skin cancers reported to INAIL during the period 2012–2017.

Materials and methods

We accessed the statistical database (*Banca Dati Statistica*) of the Italian Workers' Compensation Authority (INAIL)²⁷ in the period 2012–2017. In this INAIL database, data are coded according to two broad occupational sectors: 'Agriculture' and 'Industry and Services'; we have considered both. Within the 'Industry and Services' sector, the 'Diseases caused by UV including solar radiation' (code: 84) were selected, while for the 'Agriculture' sector we selected the 'Diseases caused by solar radiation' (code 19). For the two groups of diseases in both sectors, we extracted the number of 'actinic keratosis' (code L57.0) and of 'Epiteliomi cutanei delle sedi esposte' (Skin epitheliomas of the exposed areas) (code C44) reported to the INAIL during the considered period based on the Italian legislation.^{25,26} Unfortunately in the public area of the INAIL statistical database, the number of AK and skin epitheliomas (i.e. non-melanoma skin cancer, NMSC) is reported, but no other information on workers or on the diseases' characteristics is available.

The number of new NMSC cases, and also separately of BCC and SCC, expected in the Italian general population in 2018 was obtained from the Italian cancer registries data,¹⁸ while the Italian inhabitants in the same year from the Italian National Institute of Statistics (ISTAT);²⁸ then, the crude annual incidence rate was calculated accordingly:

Crude incidence of NMSC/BCC/SCC = Expected new cases/ Italian general population

All NMSC: 83 000/ 60 483 973 = 1.4 cases/1000 inhabitants

BCC: 64 000/ 60 483 973 = 1.1 cases/1000 inhabitants

SCC: 19 000/ 60 483 973 = 0.3 cases/1000 inhabitants

Another estimate of the incidence of BCC and SCC in Italy was also available from the study of Boi *et al.* performed in¹⁹ in the Northern part of the country: the standardized incidence rates reported in this study (61.5/100 000 and 16.3/100 000 per year for BCC and SCC respectively) were additionally considered.

To estimate the number of the occupational skin cancers expected yearly in Italy, we postulated an incidence in workers

similar to that of the general population; accordingly, the above-mentioned year/incidence rates were applied to the number of workers exposed to sUVR reported by the Italian CAREX (CARcinogen EXposure) study database.¹

As INAIL data on the reported occupational skin cancers are coded according to 'Agriculture' and 'Industry and Services' sectors, we have also separately calculated the number of expected cases in these sectors; according to CAREX, the number of workers engaged is 390 000 in agriculture and 312 100 in the other sUVR-exposed activities (other outdoor workers), respectively.

Data used in this study are from published reports, all of which had been approved by the competent ethics committees; accordingly, approval from an ethics committee for this study was not needed, nor sought.

Results

The cases of NMSC and of AK reported each year to INAIL during the period 2012–2017 are presented in Figure 1: the total number of NMSC is 205, and the range of the number of cases reported per year is 25–47, with an almost twofold increase during the whole period; for AK, the total number of reported diseases in the period is 89, and the range of the number of cases reported per year is 14–24, but without any clearly increasing trend (Fig. 1).

Considering data separately from 'Agriculture' vs. 'Industry and Service' sectors (Fig. 2), the number of reported NMSC during the whole period (2012–17) is higher in agriculture, almost double compared with the other sectors: 139 cases vs. 66, respectively. Similar considerations are also valid for AK.

Regarding the expected cases calculated according to the Italian cancer registries' data, the resulting number of annually expected NMSC in Italy for sUVR-exposed workers is 772 cases of BCC and 211 cases of SCC (Table 1). If we compare the mean

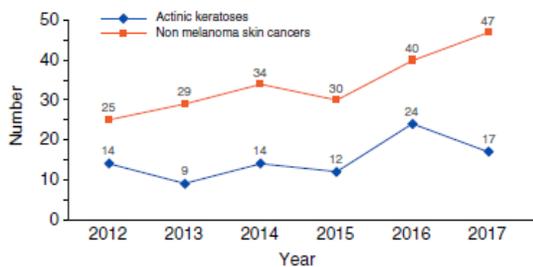


Figure 1 Number of non-melanoma skin cancers and actinic keratoses induced by occupational exposure to UV radiation, mainly comprising solar UVR*, reported to INAIL in Italy in the period 2012–2017 (all working sectors considered) [*= for further details see the Materials and methods section]

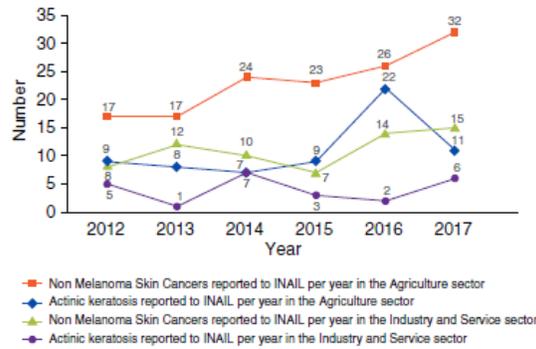


Figure 2 Number of non-melanoma skin cancers and actinic keratoses induced by occupational exposure to UV radiation, mainly comprising solar UVR*, reported to INAIL in Italy in the period 2012–2017 in the 'Agriculture' and in the 'Industry and Service' sectors, respectively [*= for further details see Materials and methods section]

number of occupational NMSC related to solar UV reported per year to INAIL in the period 2012–2017 and the expected cases, the ratio is 3.5% in the whole group of workers; considering the subgroups separately, the proportion is slightly higher for the agricultural workers compared with the other group: 4.2 vs. 2.5 (Table 1).

The number of expected cases of BCC and SCC is lower using the north Italian data of Boi *et al.*¹⁹ but even in this case there is more than one order of magnitude of difference between reported and expected cases (Table 1).

For AK, the number is expectedly higher than SCC, but no prevalence data were available from Italian cancer registries.

Discussion

The mean number of occupational NMSC reported to Italian workers' compensation authority (INAIL) in the period 2012–2017 is quite small, 34 cases/year, of which 23 in the agricultural sector and 11 in the other work sectors, while the cases expected, estimated by applying the crude incidence of NMSC in the Italian general population to the number of sUVR-exposed workers indicated by CAREX are 983 (Table 1): the ratio reported/expected is in the order of 3%.

This difference is dramatic, and we are confident that it is not related to an overestimation of the expected cases, also because the vast majority of the farmers and construction workers in Italy are usually males, and in male subjects, NMSC incidence is higher compared with females. On the contrary, the estimated number of expected occupational NMSC possibly will be lower than the real number. In fact, occupational sUVR is the main risk factor for NMSC in workers, and according to recent studies

Table 1 Occupational NMSC related to solar UV exposure (CAREX Italian exposure data) expected in Italy per year according to two different incidence estimates and comparison with the mean annual number of NMSC cases reported to INAIL in the period 2012–17

	Number of expected occupational solar UV-induced skin cancers/per year in Italy estimated according to the incidence rates of the Italian cancer registries 2018 ¹⁸ and of Boi <i>et al.</i> ¹⁹ , respectively, in:					
	All workers with occupational sUVR exposure (n = 702 100)		Agricultural workers (n = 390 000)		Other outdoor workers (n = 312 100)	
	Cancer registries 2018	Boi <i>et al.</i> ¹⁹	Cancer registries 2018	Boi <i>et al.</i> ¹⁹	Cancer registries 2018	Boi <i>et al.</i> ¹⁹
Basal cell carcinoma	772	432	429	240	343	192
Squamous cell carcinoma	211	114	117	64	94	51
Non-melanoma skin cancer (total)	983	546†	546	304†	437	243†
Percentage ratio between reported‡ vs. expected UV-induced occupational NMSC	3.5	6.2	4.2	7.6	2.5	4.5

†Data estimated BCC+SCC.

‡Reported = mean number of occupational NMSC related to solar UV reported per year to INAIL in the period 2012–2017 according to Figures 1 and 2.

of Schmitt *et al.*^{23,24} the risk in exposed workers is probably between 1.5 and 2.5 compared with the non-exposed; as we have applied to the outdoor workers the incidence rates of the general population, an overestimation of the incidence is unlikely.

Furthermore, the number of exposed workers was derived from the CAREX database, but recent studies on sUVR occupational exposure suggest a high exposure in the large majority of the outdoor workers³ that exceeds the numbers proposed by CAREX; accordingly, again an overestimation of the number of exposed workers seems highly unlikely.

For comparison, in a recent study in Canada, Mofidi *et al.*²⁹ estimated that 5.3% of all BCC and 9.3% of SCC are attributable to occupational sUVR exposure; using these estimations, the expected number of occupational BCC and SCC in Italy rises to 3392 and 1748 cases per year, respectively, compared with 711 and 211 (Table 1).

Using the data from Boi *et al.*¹⁹ the number of expected skin cancer is somewhat lower compared with the numbers estimated applying the Italian cancer registry 2018 incidence rates¹⁸ (Table 1), but this difference is coherent with the known north–south gradient of NMSC in Italy, likely related to UVR exposure: the study of Boi *et al.* was performed in the northern part of Italy, and differences in incidence in the order of more than 30% compared with the south have been reported.¹⁸ Furthermore, the study was performed more than 15 years ago, and the incidence of NMSC in Italy, as well as in most other countries, has significantly increased.^{20,21} Furthermore, in Trentino region a part of the population may spend a significant amount of time in altitudes, and as reported by Lichte *et al.* in the adjacent region of Austria, an increased prevalence of precancerous skin lesions and skin cancers should be expected in a part of the population working in the mountains.³⁰

To date, few studies approach the problem of the (under) reporting of occupational NMSC to the national compensation authorities; this is not really surprising, especially considering

that, currently, very few European countries recognize occupational sUVR-related skin cancer as an occupational disease.¹² The significant underreporting observed in this study is coherent with recent data from Denmark^{31,32} and other countries,¹² as previously highlighted.²² In order to reduce current overall negligence, with the ICD 11, released on 18 June 2018, WHO offers for the first time a post-coordination mechanism for occupational BCC, SSC and AK. Thus, creating an option to explicitly code for their occupational causation, WHO's intention is to reveal the true magnitude of occupational skin cancers. Additionally, in an unprecedented effort, WHO is currently conducting together with the International Labour Organisation (ILO) a global disease burden assessment of occupational sUVR-inflicted skin cancers.⁹ Many of the reasons for the gross underreporting of occupational skin cancers may be the same as extensively discussed recently in a large survey regarding the lack of notifications of work-related contact dermatitis in various south and east European countries, including bureaucratic hurdles, time-consuming forms, high workloads and no availability of financial incentives for doctors and patients.³³ Furthermore, at least in Italy, as it happens for other occupational diseases, usually the majority of cases are reported by occupational physicians, but skin cancers often appear when persons are in their retirement age, so that they have no access to the workers' health surveillance performed by these doctors.¹²

Other possible explanations of this large underreporting may be related to the roles and relations of the employers and employees in the companies, and are a common problem for all the occupational diseases. Among the suggested reasons of the underreporting, there are the possible legal and economic consequences for the companies when an occupational disease is recognized; also the increased job insecurity perceived in the workforce plays a relevant role, as it has been shown that precarious workers are less likely to report

1 the occurrence of a suspected occupational disease to physi-
2 cians, for fear of job loss.³⁴

3 Accordingly, it can be said that the underreporting of occu-
4 pational cancers is a well-known problem in occupational med-
5 icine, and not limited to skin cancers,^{35–37} but a reporting in
6 the order of 3% of expected cases, as we estimated in our study,
7 is entirely unacceptable. The current official German figures
8 can give an estimate of the prevalence of occupational skin can-
9 cer in a similar-sized population like Italy. Even though in Ger-
10 many, so far, only multiple AK (>5/year) and invasive SCC are
11 recognized as occupational disease since 2015, this cancer entity
12 is already the third most frequently reported occupational dis-
13 ease with 8558 cases in 2017 and figures are further rising.³⁸

14 Unlike in Germany, in Italy and many other countries, a sig-
15 nificant problem in studies on occupational skin cancer notifica-
16 tions is the inadequacy of available official data. In the public
17 area of the INAIL *statistical database*, the number of NMSC,
18 including AK, is accessible, but other relevant information on
19 workers (as age) or on the diseases (as location) is not currently
20 available. Regarding the coding of exposure, in Agriculture sUVR
21 only (code 19) is considered; while, in Industry, artificial UV
22 exposures are also included in a single subgroup (code 84); nev-
23 ertheless, specifically considering the skin, the large majority of
24 occupational cancers are presumably related to solar radiation,
25 while a small (or most likely negligible) number is expected
26 related to artificial UVR exposure, e.g. in welding.^{6,9,39} Accord-
27 ingly, we decided to merge data from Agriculture and Industry &
28 Services sectors, and to create a summarizing variable of the total
29 number of skin cancers reported to INAIL for workers occupa-
30 tionally exposed to sUVR radiation and to other UVR sources.
31 This seems legitimate, as there are no epidemiological data
32 consistently showing an increasing in skin cancer risk for
33 welders, which may be related to better skin cover in welders
34 by, e. g. clothing and total face masks to avoid painful skin
35 burns and other occupational eye injuries⁴⁰ and diseases, includ-
36 ing UV-induced photokeratoconjunctivitis and photochemical
37 cataract.^{6,41}

38 Another possible limit of studying the expected number of
39 occupational skin cancers in sUVR-exposed workers is related to
40 cancer registries: while data on malignant melanoma are largely
41 available since several years, in Italy, as in other countries, data
42 for NMSC vary significantly in quality and coverage of the terri-
43 tory, due to insufficient data harmonization and heterogeneity
44 of methods. The availability of validated questionnaires for the
45 health surveillance of people with suspected occupational der-
46 matoses could be a helpful tool to improve the registration of
47 these diseases.⁴²

48 This study has some limitations. One is that we applied the
49 crude incidence of NMSC derived from the Italian cancer reg-
50 istries to the workers population. Another limitation is that we
51 used the 2018 incidence data available for the Italian cancer

registries, while data on the occupational cancers reported to
INAIL are from the period 2012–17.

Other limitations are the impossibility to access to detailed
information regarding the workers, e.g. age, specific occupa-
tional tasks, use of personal protective equipment (PPE) and
photo-type, as well as information on the diseases, as location,
staging and grading, and multiple lesions. This information is
pivotal when studying the causal relation between outdoor work
and skin cancers in more detail.^{3,8}

However, in spite of these limitations, there are few doubts
that the vast underreporting of work-related NMSC in Italy is
real: the proportion of effectively reported diseases is less than
the 5% of the cases expected; this difference is so large that it is
almost impossible that other estimates calculated with different
methods could significantly modify the result. This underestima-
tion indicates that adequate professional skills and competences
of the occupational physicians, within a collaborative multidisci-
plinary framework with dermatologists, are needed for a more
effective health surveillance of solar UV-exposed workers, to
reduce underreporting and underestimation of occupational
skin cancers and improve prevention.

In conclusion, our study clearly shows that in Italy, as
likely in other parts of Europe, the problem of occupational
skin cancer in workers exposed to sUVR is grossly neglected,
and many cases go unnoticed, largely un(der)reported and
uncompensated. Considering solar UVR risk, workplace pre-
ventive interventions are usually missing, and the same holds
true to the regular health screening of outdoor workers – as
high a risk population – for solar UVR induced effects. This
problem is not new, and it does not involve only Italy or
Europe. Furthermore, it is not limited to skin cancers, but
for skin cancers it is particularly relevant, and the proportion
of reported vs. expected cases is dramatically low, also raising
important ethical issues. In fact, many workers cannot receive
adequate medical care and compensation for severe and
highly chronic occupational actinic damage acquired during
their working life. Moreover, because of the vast underreport-
ing, respective authorities and governments lack adequate
representation of the true magnitude of the phenomenon,
and consequently, the preventive measures needed are insuffi-
ciently implemented.

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