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A One-Month Monitoring of Exposure to Solar UV Radiation of a Group of Construction Workers in Tuscany

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Abstract: Solar radiation exposure at work is a relevant heath risk in the construction sector. Our objective was to monitor for a full month the individual solar ultraviolet radiation (UVR) exposure of a group of three construction workers active in Siena (latitude = 43°19′ N), a town in Tuscany (Italy). We used personal electronic dosimeters "X-2012-10" (Gigahertz, Turkenfeld, Germany) to register the UV irradiance in the UVA and UVB/C regions separately and we consulted a specific database to retrieve the corresponding ambient erythemal UVR dose (cloud-free conditions). In spring, construction workers from central Italy received a quite variable UVR dose, between 0.9 standard erythemal doses (SED) and 15.6 SED/day, 5.7 on average. Considering the proportion with respect to the potential environmental exposure, personal exposure resulted between 2.7% and 31.2% of the ambient erythemal dose, with a mean value of 12.5%. Cumulatively, the three construction workers received in one working month a UVR dose of more than 120 SED. In a year, we estimated that a construction worker from Tuscany region is exposed to about 750 SED. This data demonstrates that construction workers in Italy are exposed to extremely high levels of solar UVR, with a relevant risk of developing adverse health effects related to the potential accumulation of UVR-induced damage in susceptible biological tissues, such as the skin and the eyes.

Keywords: solar radiation; ultraviolet rays; exposure assessment; construction; skin cancer prevention; workers health; personal dosimetry; occupational safety and health

1. Introduction

Solar radiation (SR) exposure represents an important, even if sometimes neglected, occupational risk, with a high potential for inducing adverse health effects in exposed workers, if no adequate prevention is emplaced [1]. The most hazardous component of the optical spectrum of SR is ultraviolet radiation (UVR), which can induce by photochemical mechanisms various acute and long-term adverse effects, mainly in the skin and the eyes of exposed subjects [2]. Both SR and UVR generated by artificial sources are classified as carcinogenic agents of the group 1 of the International Agency for Research on Cancer (IARC) [3]; moreover, each of the three components of the UVR, i.e., UV-A (wavelength—λ = 315–400 nm), UV-B (λ = 280–315 nm), and UV-C (λ = 100–280 nm), is separately classified in the same IARC group as well [3]. SR represents the most important cause of skin tumors, and excessive UVR exposure is associated to the development of the main types of skin cancers, including malignant melanoma (considered to be mainly associated to repeated sunburns and intense intermittent exposure, especially at a young age) [4] and non-melanoma skin cancers (NMSC—including basal and squamous cell carcinomas, usually associated to long-term solar UV exposures, e.g., the exposure patterns typical of outdoor work activities) [5]. Other long-term skin effects are actinic keratosis and photo-aging, considered to be pre-cancerous alterations (actually, there is discussion on the possibility to consider actinic keratosis as in situ squamous cell carcinomas) [6]. Of course, acute effects are also possible, such as the well-known sunburns and other skin reactions such as photo-toxic and photo-allergic skin erythema, as well as exacerbation of pre-existing skin diseases, such as LES or psoriasis [6]. The other important target of optical radiation is the eye: also, in this case, both acute and long-term effects are possible. Among acute ones, there are UV-induced photokeratitis/conjunctivitis, which can usually happen after intense exposure to reflected UV rays (e.g., by snow) [6,7]. UVR-induced long-term eye effects are mainly pterygium [6–8] and cataract [6,7,9]. The WHO estimates a population-attributable fraction (PAF) of these diseases caused by solar UVR exposure of respectively 42–74% for pterygium and 25% for cortical cataract [6]. Recently published research suggests that cumulative solar UVR exposure is associated with nuclear cataract as well [9]. Another very frequent chronic eye disease is age-related macular degeneration. Additionally, for this multi-factorial pathology, there are several epidemiologic studies suggesting a relation with long-term SR exposure, even if the evidence of an association is somewhat weaker compared to the other ocular diseases mentioned above [6,10]. The exposure to SR is also a recognized risk factor for eye tumors, very rarely occurring; both ocular melanoma and squamous carcinoma of the cornea and conjunctiva are possible [11].

Considering the relevancy of the potential adverse effects, excessive solar UVR exposure at work should be avoided and outdoor workers (OWs) need to be adequately protected against UV rays. Unfortunately, the sun-exposure habits and the protective behaviors of the Italian OW seem inadequate for an appropriate prevention of the risk, especially in the construction sector [12]. This is not only related to the scant perception of the possible health hazard but also to the lack of recognition of solar radiation as a specific occupational risk in the occupational health and safety legislation (both Italian and European legislation in this field only consider specific occupational risk as artificial UVR, while solar radiation can only be managed as a generic occupational risk) [1].

In order to improve the perception of the risk and strengthen preventive measures, specific sun-safety campaigns for outdoor workers, health surveillance programs, and occupational solar UVR exposure assessments should be carried out [12]. As for other occupational risk factors, also in the case of UV exposure, a possibility is to perform risk evaluation based on ambient and individual exposure data. In the former case, UVR exposure levels can be acquired with spectroradiometers or, even if less precise data, through specific databases [2,7]. Considering individual exposure, solar UVR levels can be measured with personal dosimeters, usually electronic or with a polysulfone film [2,7]. There are several published studies showing the results of personal UVR measurement campaigns in construction workers [13–20], but in most of the cases, exposure levels are representative of short-term exposure, with measurements collected during some hours or a few days. Individual UVR exposure data can be reported as radiant energy (J) and irradiance (Watts per square meter—W/m^2) [2,7]. More often, the results of the personal UVR measurements are reported from the studies in this field as the corresponding effective quantities, which can be directly associated to the ability of inducing appreciable effects, usually skin erythema: A "standard erythemal dose" (SED) can be considered representative of an individual exposure in a standard (i.e., adjusted for skin UVR sensitivity) individual of 100 Joule/m^2 [2,7]. In Table 1, a synthesis of recent studies available with personal solar UVR exposure measurements in the construction sector is shown [13–20].

Table 1. Short-term measurements of occupational solar ultraviolet radiation exposure in groups of construction workers published in recent studies. Results of the measurements are in standard erythemal doses (SEDs) per day.

Study	Population, Month/Season, Place	Results of the Measurements in SED/Day
Boniol M et al., 2015 [13]	126 workers, Summer, France (NB: no direct measurements: estimates based on questionnaire and UV meteorological data)	10.1
Gies P, Wright J., 2003 [14]	493 workers, September—November, Queensland (North Australia) (NB: only 4 h of measurements)	Pavers–Tilers 10 Dogger 8.3 Traffic controllers 7.7 Roofers 7.6 Fencers 6.2 Riggers 6 Plant operators 3.1 Painters 1.1 Cabinet makers 0.3 Laborers 5.9 Steel Fixers 5.6 Inspectors 2.5 Concreters 4.7 Bricklayers 4.7 Supervisors 3.4 Carpenters 5.3 Other Workers 4.9 Plumbers 5.7v All workers 4.5
Hammond V et al., 2009 [15]	77 workers: 39 construction and 19 road workers, Summer (December), New Zealand	5.25 for construction workers 5.31 for road workers
Kovačić J et al., 2020 [16]	4 workers: Zagreb (latitude: 45.8° N, altitude 128 m), Croatia, June–October	2.8 (median daily exposure on average based on five months, range:1.1 in October–4.2 in August)
Milon A et al. 2007 [17]	20 workers, Switzerland, July–September, at three different altitudes: plain (500–600 m) middle (1400–1500 m) high mountain (2000–2500 m)	11.9 in plain 21.4 at middle altitude 28.6 in high mountain
Moldovan H et al., 2020 [18]	10 workers, Romania, April–October: 5 workers in Tirgu-Mures (latitude: 46° 32′′ N; longitude: 24° 33′ E)	4.2 (mean exposure on average based on seven months, range: 2.0 in October–6.8 in April) in Tirgu-Mures
	5 workers in Bucharest (latitude: 44° 25′ N; longitude: 26° 06′ E)	3.2 (daily exposure on average based on six months, range: 1.3 in October–4.8 in July) in Bucharest
Serrano MA et al., 2013 [19]	8 workers, Valencia, Spain	6.11
Wittlich M et al., 2020 [20]	3 workers, April–October, Denmark (latitude 56° N)	3.3 (daily exposure on average based on seven months, range: 0.4 in October–7.2 in July)

Nevertheless, it should be considered that short-term personal UVR exposure measurements are not fully appropriate for an assessment of the UV risk at work, considering in particular the prevention of long-term UVR-induced adverse effects. For a more representative evaluation of the risk of cumulative UVR exposure in the construction sector, as well as in other outdoor jobs, an estimate of the long-term exposure should be provided. Recently, Wittlich et al. proposed a new method to evaluate solar UVR exposure in outdoor workers [21], and several masons have been monitored for their solar UVR exposure for various months across Europe [20].

The objective of this article was to report Italian data collected in Siena, a town of the Tuscany region in Italy (latitude = 43°19′ N). Tuscany and related to a one-month monitoring of solar UVR personal exposure with individual electronic dosimeters in a small group of construction workers. We also aimed at estimating the cumulative annual UVR dose received by these workers, comparing the results of the measurements with ambient data obtained through specific databases.

2. Materials and Methods

2.1. Study Context

We report an occupational solar UVR exposure evaluation based on data collected in Tuscany, Italy, in May–June 2017. The study is part of a larger international UVR measurement campaign supported by the European Academy of Dermatology and Venerology (EADV) and the EU Horizon 2020 COST Action "StanDerm" [20], and the preliminary data were presented to the 20th IEEE International Conference on Environment and Electrical Engineering (IEEE EEEIC) [22].

The UVR exposure measurement campaign was proposed as part of an occupational risk evaluation procedure to a construction company active in the district of Siena (latitude = 43°2′ N; longitude = 11°2′ E), which voluntarily accepted to join the campaign. No economic benefits were provided to the company, nor to the workers and the researchers involved. The UVR measurements were planned in the late spring/early summer season, when the meteorological conditions in Tuscany are usually favorable, allowing us to monitor the solar UVR exposure of construction workers outdoor for several consecutive days. In fact, during this period, it is more likely that construction workers perform for longer times activities, such as roofing, while other activities performed inside the construction site in shaded areas are more common in winter and autumn. We considered a period of 32 days, from 22 May to 22 June 2017, in order to have an evaluation of occupational exposure representative of a standard working month. In fact, during the considered period, the total number of working days in the construction company was 23 days (all Saturdays and Sundays were non-working days for the company, as well as 2 June, a national holiday in Italy).

2.2. Study Population

In the small construction company that joined our solar UVR measurements campaign, four construction workers were employed, all males. The aim of the proposed research was explained to the workers, an informed consent was collected, and they chose to participate in the campaign as volunteers.

Unfortunately, during the campaign, we experienced some problems related to the collection and/or the transmission of the UVR exposure data for one of the four workers, and a relevant number of measurements was lost, with a total of only five days with reliable data for him in the whole month monitored. For this reason, we had to exclude the few results related to this fourth subject, and we present here the personal solar UVR exposure data at the work of three male construction workers. As reported above, we consecutively measured solar UVR exposure in these workers for 23 working days, representative of a standard working month, with a theoretical maximum of 69 days to be monitored in total for the three workers.

2.3. Measurements of Individual Solar UVR Exposure at Work

UVR exposure data in the three construction workers were collected with personal electronic dosimeters according to the GENeration and Extraction System for Individual exposure to UV (GENESIS-UV) methodology [21]. The electronic data logger included in the GENESIS-UV system is a X-2012-10 (Gigahertz, Turkenfeld, Germany) UV dosimeter, measuring UV irradiance separately in the UV-A and UV-B/-C regions (Figure 1) [21]. Each worker was instructed to wear the dosimeter on the upper left arm in a standard position for all the working days, usually from 9.00 a.m. to 5.00 p.m. (Figure 2). The dosimeter was equipped with a simple switch, and the workers were instructed to turn on the instrument in the morning before starting work outdoors and turn it off in the evening, at the end of the work shift. Moreover, in case of relevant time being planned to be spent working indoors in a specific day, or in case of bad meteorological conditions preventing the possibility to work outside, workers were instructed to turn off the dosimeter. Furthermore, every week on Friday, it was required to connect with a cable the dosimeter to a tablet PC given to the workers as part of the GENESIS-UV system. Through the tablet PC, connected to the internet, the measured personal UVR exposure data could be stored in the server based at the "Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung"(IFA, i.e., Institute for occupational safety and health of the German Social Accident Insurance) in Germany, where the data were further processed and analyzed (Figure 1).

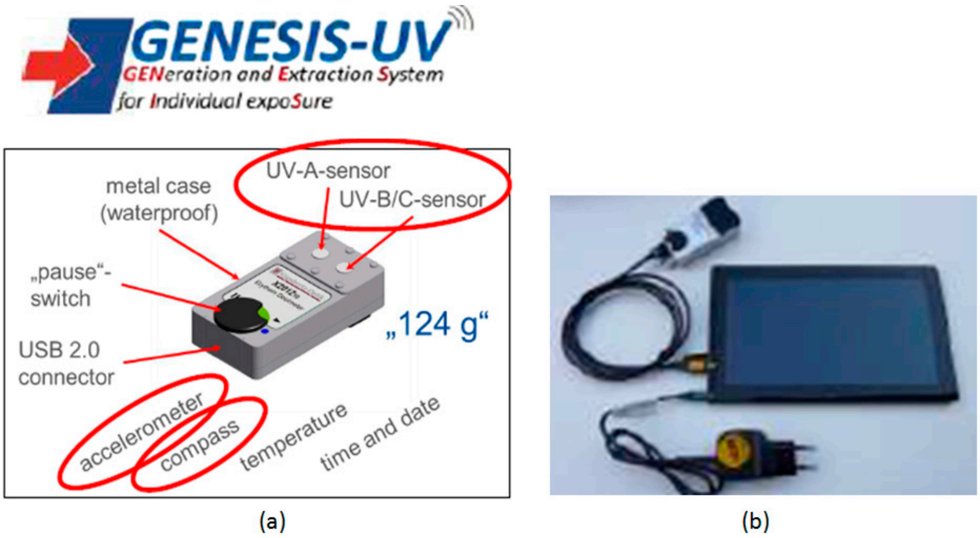

Figure 1. The GENESIS-UV system for long-term occupational UV exposure monitoring: (**a**) the electronic UV dosimeter X-2012-10 and its characteristics; (**b**) the dosimeter connected to a tablet PC.

Figure 2. A construction worker in Tuscany wearing the GENESIS-UV dosimeter on the upper left arm.

2.4. Estimates of Ambient Solar UVR Exposure at the Workplace and Reconstruction of the Cumulative Annual UVR Exposure of the Workers

In order to estimate the daily ambient solar UVR exposure at the construction site where the three workers were employed, we retrieved the erythemal UVR dose in clear sky conditions for each worked day through a freely available database of the European Space Agency (ESA) [23]. As these data refer to cloud-free conditions, we also acquired measurements of atmospheric precipitations, which can be an indirect estimate of cloud cover, from the archives of the regional hydro-geological service. We consulted the data of the meteorological station Monteroni d'Arbia (latitude = 43°14′ N; longitude = 11°25′ E) [24]. Unfortunately, Italian data available in the TEMIS archive of the ESA do not cover the town of Siena (latitude = 43°19′ N; longitude = 11°19′ E), and therefore we used as a proxy the measurements available for Rome (latitude = 41°53′ N; longitude = 12°30′ E), as it is located about 230 km south from Siena. Considering that Rome has a lower latitude than Siena, but it has an average altitude of 21 m above the sea level, while Siena is located about 322 above the sea level, and in light of the fact that UVR intensity increases by approximately 7% for each kilometer of elevation [7], we can expect the average UV index of the two cities to be similar.

We then calculated, for each of the days monitored, the percentage of ambient clear-sky UVR dose received by the workers, and we used the average ratio personal/environmental exposure in the monitored month, considering all the three workers, to reconstruct the annual cumulative UVR dose received by a standard construction worker in Tuscany. For this purpose, we approximated the ambient erythemal clear-sky UVR dose in Siena in 2017 to about 600 kJ/m^2 (i.e., approximately 6000 SED) according to the TEMIS data [23] and based on about 230 working days (excluding all Saturdays and Sundays, and a standard one-month Italian holiday period, two weeks in middle August and two weeks between the end of December and beginning of January).

3. Results

We collected occupational solar UVR exposure data for three construction workers in Tuscany in a period of one month between 22 May and 22 June 2017, counting 23 working days. As a whole, we retrieved measurements for 40 working days considering the 3 workers, on a theoretical maximum of 69 working days in the observation period. Accordingly, our monitoring covered the 58% of the maximum. Considering the different days, we were able to cover with measurements from at least one worker 21 out of the 23 days of the working month (91.3%). The results of the daily measurements for the three workers are reported in Table 2.

For worker 1, we registered a personal solar UVR exposure ranging between 2.9 and 14.1 standard erythemal doses per day (SED/day), based on the 12 working days measured. For worker 2, we measured individual UVR levels between 0.8 and 15.6 SED/day based on 15 working days with data from the GENESIS-UV dosimeter. Finally, for worker 3, we collected data showing personal exposure to solar UVR varying between 1.4 and 9.5 SED/day, based on the 13 working days measured (Table 2).

The mean daily individual occupational solar UVR exposure for the three workers resulted in the range between 1.4 and 12.6 SED/day, with 5.7 SED/day on average in the whole period monitored (Table 3). In the same day, the daily environmental erythemal UVR dose in clear-sky conditions according to the European Space Agency data [23] varied between 39.1 SED/day measured on the 25 of May and 53.3 SED/day registered on 13 June. Atmospheric precipitations above 0 were recorded only on 7 June (0.2 mm) and on 16 June (1.4 mm). On average, the ambient exposure in the monitored period was 46.8 SED/day. According to these data, the percentage of individual versus ambient solar UVR exposure varied between 2.7% registered on 16th June and 31.2% calculated for 22 May, with 12.5% on average (Table 3).

Considering cumulative solar UVR exposure, a construction worker in Tuscany received about 120.4 SED in one month. Over the same period, the ambient exposure in clear-sky conditions resulted in about 1000 SED. In light of an average ratio of personal vs. environmental exposure of 12.5% and of an ambient erythemal clear-sky UVR dose of about 6000 SED in 2017, we estimated that a construction worker in Tuscany receives up to 750 SED/year during their occupational activity.

Table 2. Individual (40 daily measurements) occupational solar UVR exposure measured for three construction workers in Tuscany during 23 working days (22 May–22 June 2017) in standard erythemal doses per day (SEDs/day).

Working Day	Worker 1	Worker 2	Worker 3
22 May	14.0	15.6	8.1
23 May	/	3.2	/
24 May	14.1	5.9	9.3
25 May	4.4	5.7	6.0
26 May	/	6.1	/
29 May	/	6.5	/
30 May	/	10.0	/
31 May	/	4.3	4.4
1 June	/	4.7	6.1
5 June	4.7	0.8	2.5
6 June	5.6	2.6	2.4
7 June	8.3	4.2	/
8 June	/	8.3	9.5
9 June	5.5	/	/
12 June	5.5	5.9	4.1
13 June	3.6	/	2.0
14 June	5.3	/	/
15 June	/	/	/
16 June	/	/	1.4
19 June	/	/	/
20 June	2.9	/	/
21 June	10.0	/	7.3
22 June	/	6.1	2.0

/ = no daily exposure data available for the worker.

Table 3. Daily environmental erythemal UV dose in clear-sky conditions and mean individual occupational solar UVR exposure of the three construction workers in Tuscany during 21 working days (22 May–22 June 2017) in standard erythemal doses per day (SED/day), with atmospheric precipitations in the days considered and percentage of individual versus ambient exposure.

Working Day	Environmental Erythemal UVR Dose in Clear Sky Conditions (SED/Day)	Atmospheric Precipitations in mm	Mean (±Standard Deviation) Personal UVR Exposure of the 3 Workers in SED/Day	Percentage of Individual vs. Environmental Exposure (%)
22 May	40.2	0	12.6 ± 3.9	31.2
23 May	40.2	0	3.2 *	8.0
24 May	40.7	0	9.8 ± 4.1	24.0
25 May	39.1	0	5.4 ± 0.8	13.8
26 May	40.8	0	6.1 *	14.9
29 May	45.3	0	6.5 *	14.3
30 May	46.4	0	10.0 *	21.6
31 May	49.0	0	4.3 ± 0.1	8.9
1 June	44.0	0	5.4 ± 1.0	12.3
5 June	48.6	0	2.7 ± 1.9	5.5
6 June	46.6	0	3.5 ± 1.8	7.6
7 June	46.5	0.2	6.3 ± 2.9	13.5
8 June	47.7	0	8.9 ± 0.8	18.7
9 June	47.3	0	5.5 *	11.6
12 June	52.9	0	5.2 ± 0.9	9.8
13 June	53.3	0	2.8 ± 1.1	5.2
14 June	53.0	0	5.3 *	9.9
16 June	50.4	1.4	1.4 *	2.7
20 June	52.5	0	2.9 *	5.5
21 June	49.0	0	8.7 *	17.7
22 June	50.4	0	4.1 *	8.0

* = no standard deviation to be calculated as personal UV exposure data of only one worker was available for the day.

4. Discussion

The results of our occupational solar UVR exposure assessment in a small construction company operating in Tuscany, in the center of Italy in late spring/early summer, show very relevant individual UVR exposure levels. This observation is coherent with data reported for construction workers from other countries (Table 1) [13–20], and with other Italian data registered for other occupational groups in approximately the same region and season [25,26].

As a matter of fact, occupational solar UV risk in Italy is not recognized in the same way as other occupational risks: No occupational limit values are available and no specific requirements are in force for risk assessment at the workplace or health surveillance of exposed workers, while only general recommendations can be considered [27–29]. For these reasons, we could not compare the solar UVR exposure levels we detected with occupational threshold limits or other exposure assessments in similar companies and territories. Nevertheless, according to the scientific literature and with ICNIRP recommendations [2,7], we consider an exposure value between 1 and 1.3 SED/working day as an appropriate limit level [30,31]. The construction workers we monitored largely exceeded this exposure level, being about 5 times above this level on average in the monitored month, with a peak of more than 12 times for a single worker. Considering all the data registered with the personal electronic dosimeters, corresponding to a total of 40 working days measured, we observed an overcoming of the 1.3 SED/day level for 39 out of 40 daily measurements.

We then compared the personal exposure levels collected with ambient UVR data available from a website of the European Space Agency [23]. The methodology adopted can be easily applied in further studies, representing a reliable way to estimate long-term individual UVR exposure levels of outdoor workers.

The results of the personal measurements we obtained are, not surprisingly, highly variable, as observed also in other studies [13–20], while the environmental data show a regular upward trend during the monitored month. On average, we considered a mean proportion of personal versus ambient exposure of 12.5%, but the point values ranged between 2.7% and 31.2%. For construction workers, this high variability can partially be explained with several different tasks performed during a working day, with different postures adopted, different amounts of time spent outdoors (sometimes always outdoors during the work-shift, other times only outdoors for a part of the day), and different work environments depending on the evolution of the construction site and the part of the building to be developed (more or less shaded from UVR, with or without relevant reflections, etc.). Moreover, protective habits are important. As solar UVR risk is not adequately perceived, clothing is mainly determined by the external temperature; in case of lower temperature or of adverse meteorological conditions (wind, rain), the construction workers are usually better protected from UVR, but when the climate is warmer, the workers tend to use less such protection. Furthermore, it should be noted that the headgear used by the construction workers is not useful for reducing solar UVR exposure to the face, neck, and ears, and sunscreen at work is almost completely neglected [12].

Our results also show that the highest levels of individual solar UVR exposure were registered at the end of May, when the ambient UVR exposure was lower compared to late June. In general, the trend of the daily personal UVR measurements seems to rather descend, instead of ascending, as is the case with the environmental erythemal UVR doses towards the summer period. A possible explanation is that when the external temperature is relatively low, workers, who not adequately perceive the health risk related to UVR, are more prone to work in direct sunlight during midday, while in case of a hot summer day, they tend to seek shade and avoid working in the direct sun during the central hours of the day, when UVR doses peak.

Another important objective of our research was to estimate the cumulative individual exposure of the workers. For a construction worker in central Italy in late spring/early summer, we estimated that he can receive up to 120 SED approximately, corresponding to 16% of a cumulative personal UVR dose of about 750 SED per year. In addition, it should be noted that, most likely, also a relevant UVR exposure in leisure time can be expected for these subjects, projecting the estimates to an annual UVR dose of probably more than 1000 SED. This is an extremely high cumulative dose, especially considering that UVR is a well-established human carcinogen, eliciting tumor induction by DNA damage and tumor promotion by immunosuppression. Immediate actions are needed to improve the prevention of UVR-induced adverse health effects in Italy. Outdoor work is a major factor determining relevant levels of cumulative solar UVR exposure, and accordingly specific sun-safety interventions in sectors, such as construction, should urgently be put in place.

Our study also has some limitations. First of all, due to various technical and organizational problems, we missed a relevant number of measurements in the monitored month but considering the 3 workers and the 23 working days available, we were able to cover 91% of the working days targeted. The sample size of only three workers is very small, but we believe that despite this limitation, providing continuous personal UV exposure data of real workers during a one-month period can be important to build knowledge on different patterns of real exposure of outdoor workers, in addition to existing studies adopting specific models [13,32–36] or applying dosimeters on mannequins [37,38].

Another possible limitation is related to the placement of the dosimeter. We fixed it in a standard position on the upper left part of the arm, as required by the GENESIS-UV methodology for data standardization. This position was selected as it was judged to be the best compromise between an adequate representation of the individual solar UVR risk and the need for no interferences with working activities. We are aware that, in particular, in the case of adoption of specific working postures by construction workers, and especially considering the exposure of body sites, such as the forehead or the neck, our assessment in some cases may have underestimated the real individual solar UVR exposure.

Finally, a further limitation is related to the estimate of the environmental UVR doses. Unfortunately, we did not have the possibility to perform ambient measurements with UVR spectro-radiometers, and we had to retrieve data from a specific online database [23]. Available archived data in this database for the year 2017 can only provide clear sky erythemal UVR doses, suggesting that, for some days, a possible overestimation of the real environmental UVR dose at the ground could be expected. Nevertheless, the meteorological conditions during the monitored month were quite good, as also confirmed by the data we collected on atmospheric precipitations. Accordingly, we believe that cloud cover has not relevantly affected the results of the UV measurement campaign during the period considered. Another factor, mentioned also in the method section, that could have possibly determined a less precise estimate of the ambient solar UVR doses is the unavailability of specific data for the district of Siena in Tuscany from the database we consulted. Accordingly, we had to consider available data from the city of Rome (less than 200 km in the southern direction, at a slightly lower latitude and altitude).

5. Conclusions

Our research shows extremely relevant occupational exposure levels to solar UVR in a group of construction workers in central Italy, considering both the acute daily exposure in spring and summer and the long-term cumulative annual exposure to UVR. For the workers, the level of 1 standard erythemal dose per day was regularly exceeded, often by several times. The UVR dose accumulating in the skin over years of outdoor work is strongly related to the occurrence of skin cancers. There are no other carcinogenic occupational agents for which such an excessively high exposure would be tolerated. For these reasons, considering the demonstrated high exposure levels and the relevant risks of adverse effects, our study supports the need for urgent action in Italy to improve the prevention of solar radiation risks at work, in the construction sector, as well as for other outdoor workers.

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