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Original article

Protective Measures From Solar Ultraviolet Radiation for Beach Lifeguards in Tuscany (Italy): Shade and Clothing Strategies

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A B S T R A C T

Background: The exposure to solar ultraviolet radiation is a significant risk factor generally underestimated by outdoor workers and employers. Several studies have pointed out that occupational solar exposure increased eye and skin diseases with a considerable impact on the lives and productivity of affected workers.
The main purpose of this study was to evaluate the effectiveness against ultraviolet radiation of some measures recently undertaken for the protection of lifeguards in a coastal area of Tuscany.
Methods: Different shading structures (gazebos and beach umbrella) were tested during a sunny summer's day on a sandy beach by means of two radiometers; the UV protection offered by some T-shirts used by lifeguards was also tested in the laboratory with a spectrophotometer.
Results: The analysed shading structures strongly reduced the ultraviolet radiation by up to 90%, however a not always negligible diffuse radiation is also present in the shade, requiring further protective measures (T-shirt, sunglasses, sunscreen, etc.); the tested T-shirts showed a very good-excellent protection according to the Australian/New Zealand standard.
Conclusion: Results obtained in this study suggest how the adoption and dissemination of good practices, including those tested, could be particularly effective as a primary prevention for lifeguards who are subjected to very high levels of radiation for long periods.

1. Introduction

Outdoor workers are exposed to the effects of weather elements, among these, heat and high levels of solar ultraviolet radiation are two potential important environmental hazards.

Exposure of outdoor workers to high levels of solar ultraviolet (UV) radiation impacts mainly on the skin, eye, and immune system. The effect on skin and eyes can be classified as acute and chronic: the former represented by sunburn for skin and photoconjunctivitis and photokeratitis for eyes, the latter by keratinocyte

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carcinomas (KCs) and cutaneous melanoma (CM) for skin, and pterygium and cataract for eyes [1].

KCs are the most common skin cancer in Caucasian populations with an incidence in 2017 of 7.7 million cases worldwide [2,3]. There are two main types of KC: basal cell carcinoma (BCC), the most common type, and squamous cell carcinoma (SCC). The occurrence of SCC is associated both with total and occupational solar exposure, while for BCC a non-occupational or recreational sun exposure is considered the main cause [4,5].

According to a recent large case-control study in eight European countries, the risk of developing SCC and BCC is estimated to triple with five or more years of outdoor work [6].

KCs incidence is rising worldwide, it is rarely fatal, but even if detected at an early stage leads to a life-long chronicity with recurrent newly forming lesions, entailing an ongoing need for treatment [7].

CM is mainly associated with intermittent exposure to high-intensity sunlight (usually recreational), rather than chronic exposure, typical of outdoor occupations [5,8]. This relation between type of sun exposure and type of skin cancer is nowadays probably too schematic because in the real life different types of tumours can form on the skin of the same person. As reported in many studies, more and more frequently CM is diagnosed in patients followed for BCC or SCC or precancerous lesions and vice versa [9–11].

Unfortunately, the UV radiation risk is still little known and underestimated by outdoor workers and employers, as highlighted for example by the Plan of the Tuscany Region (Italy) "Risk from Solar Ultraviolet Radiation in Outdoor Workers," which investigated several employment sectors [12,13].

Most working, recreational and sporting activities are associated with personal exposure levels above the internationally proposed threshold limit value [14–26]. Concerning beach lifeguard activities, few studies have quantified professional UV exposure [27,28].

A protocol for a systematic review on the effectiveness of interventions to reduce exposure to occupational solar ultraviolet radiation among outdoor workers was proposed by Modenese el al. (2021) [29]. Measures can be related to primary, secondary and tertiary prevention. The first includes any preventive action aimed at reducing the incidence of cancer in humans [30–32] (including adequate risk assessment process, implementation of specific action to reduce exposure, information for workers and the provision of personal protection equipment). The second is represented by methods that can lead to the early detection of precancerous conditions or cancers [13,33]. Finally, the third interventions are performed when the adverse effects are already manifested [34].

A positive effect was stated in limiting the occupational solar UV radiation exposure of these workers [35], however, precise and valid data on the effectiveness of interventional studies for the reduction of the incidence of SC in solar UV exposed workers are still lacking.

A multifactorial approach based on appropriate combinations of clothing, hat, sunglasses, sunscreen application and shade is essential for the minimization of exposure to solar UV during outdoor activities [36].

Several studies quantified the UV protective role of clothing [37,38], and shading structures [39–44], among these some considered beach umbrellas [45–47].

In support of the existing evidence, the main aim of this study was to evaluate the protection offered by some shading structures and different types of T-shirt commonly used by lifeguards in the analysed coastal area of Tuscany. In particular, it was investigated whether these protection systems were sufficient to comply with the recommended occupational exposure limits and the results may be supportive in providing more suitable suggestions for avoiding lifeguard health impacts as a result of prolonged exposure to UV radiation combined with hot conditions.

2. Materials and methods

2.1. Characterization of UV protection offered by shading structures

2.1.1. Site description, UV climatology, UV units, and weather conditions

The UV irradiance measurements were made on July 13th 2018, with a clear sky, in Viareggio (lat. 43°.8428 N, long. 10°.2467 E, 0 m a.s.l) on a sandy beach with an albedo of 9%, calculated as the ratio of reflected (upwelling) irradiance to incident (downwelling) irradiance measured by two broadband radiometers with spectral response close to the erythemal action spectrum (see later). The day was representative of one of the most critical situations that can occur in the area, but other meteorological conditions might be worthy of further studies. The diffuse component of the UV solar radiation on a horizontal surface at noon was about 55% while the sun position during the day is shown in Supplementary Table S1; the beach was north–south oriented and the sea was to the west.

A climatological characterization in terms of UV Index (UVI) and daily number of Standard Erythemal Doses (SEDs) was done, for the 2009–2018 period, using GOME-2 data (Global Ozone Monitoring Experiment-2, https://acsaf.org/offline_access.php).

One unit of UVI is defined as 25 mW of Biologically Effective UV radiation for Erythema ($UVBE_{eryth}$). UVI values are grouped into exposure categories, low < 2, moderate 3 to 5, high 6 to 7, very high 8 to 10 and extreme over 11 [48].

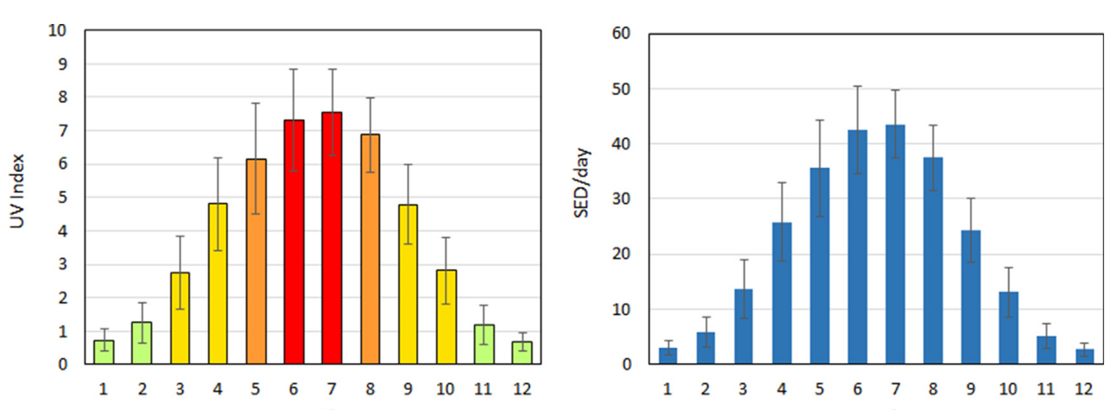

Fig. 1. UVI at solar noon (left) and cumulated daily $UVBE_{eryth}$ (in SED) (right) in Viareggio, Italy; vertical bars represent standard deviation. Period 2009-2018 using UV GOME-2 data.

The SED is defined as 100 J/m^2 of $UVBE_{eryth}$ [49], while the Minimal Erythemal Dose (MED) is defined as the $UVBE_{eryth}$ threshold beyond which erythema occurs after the first exposure of the season; for a "never tans, always burns" skin type (phototype I) [50] 1 MED is defined as 2.10 SED. For individuals with higher resistance to sunburn, the MED corresponds, although with a large variability between individuals, to approximately 2.5, 3.0, 4.5, 6.0, and 10.0 SED for skin phototypes II, III, IV, V, and VI, respectively [51]; however, people of any ethnic background, even those who always tan or rarely burn, can get skin cancer even if the risk decreases increasing the phototype class and so protective measures are always required.

The recommended threshold limit value (TLV) for outdoor workers corresponds to 1–1.3 SED (0.5-0.6 MED for phototype I) over a period of 8 hours [21,52,53].

For the same study day, meteorological data of air temperature and humidity, wind speed and global radiation were collected every 15 minutes from a meteorological station (Hydrological Section of Tuscany Region) on the seafront of Viareggio. These data were used to assess (by using the UTCI software code "version a 0.002", freely available online, http://www.utci.org/) what is considered the state-of-the-art of indicators for the evaluation of thermal stress in an outdoor environment, the Universal Thermal Climate Index (UTCI). UTCI is an equivalent temperature (°C), referred to a person generating 135 W m^{-2} (therefore a value on the border between low and moderate metabolic rate) based on the most recent scientific progress in human thermo-physiology, biophysics, and the heat exchange theory [54,55].

2.1.2. Instrument description

Measurements were performed by means of two inter-calibrated broadband radiometers (Solar Light CO Inc., Model 501A) with a wavelength interval of 270–340 nm, a spectral response close to the erythemal action spectrum [56] and an expected daily accuracy of ±5%. The output of the radiometers is in terms of $UVBE_{eryth}$. A data logger (positioned between gazebo 1 and the umbrella) was connected with the two radiometers by means of two electric cables which allowed measurements to be performed on both shading structures.

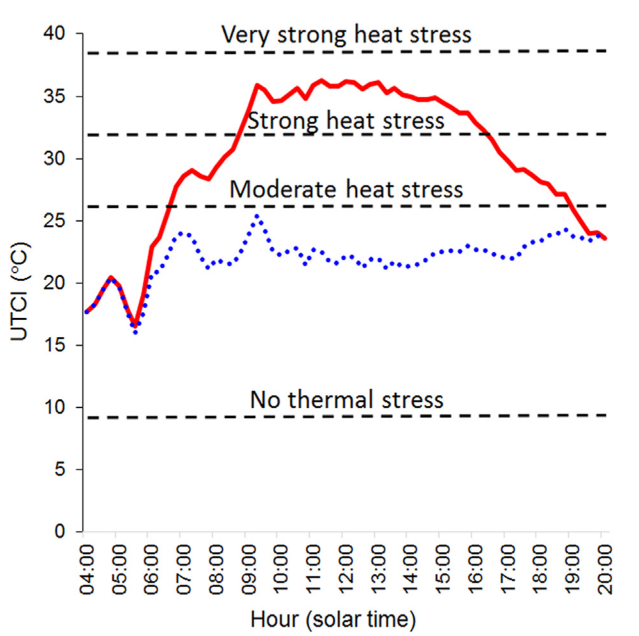

Fig. 2. Daily trend of the UTCI calculated in conditions of direct exposure to solar radiation (solid line) and in shaded conditions (dotted line). The dashed horizontal lines indicate the thresholds that identify specific heat stress categories.

2.1.3. Description of shading structures

The analysed shading structures were three gazebos recently positioned on the beach as a sun protection measure for lifeguards and a typical beach umbrella used by tourists.

The first gazebo ("gazebo 1"), 2.7 m × 2.7 m in size, was placed on the upper surface of a lifeguard tower (3 m × 4 m) about 2.5 meters above the ground; the gazebo cover was horizontal at 2 m from the tower's upper surface.

The other gazebos, "gazebo 2" (2 × 2 m) and "gazebo 3" (3 × 4 m) had the horizontal cover at 1.8 m, from the ground and from a wood platform raised 0.50 m from the ground, respectively. The common beach umbrella had a diameter of 2.40 m, a height of 1.80 m at the apex (when stuck into the ground) and of 1.7 m at the margins. All the covers of different shading structures were in fabric, except for gazebo 3, which was in wattle. The transmittance of the cover of the different shading structures was measured using the above mentioned broadband radiometers, one positioned in full sun and one under and in contact with the cover. It is a non-standard method which allows, at least in relative terms, to evaluate the transmittance of the different covers. The gazebos were on the beach close to the sea, while the umbrella was further inland on the beach in the typical row configuration, however in the row nearest the sea. The measurements under the umbrella, although not fully comparable with those of the gazebos, also because influenced by other umbrellas and chairs, except in the westward direction, could anyway provide useful information on a widely used type of protection in a real situation.

2.1.4. Sequence of measurements

One radiometer was positioned under full sun, with the other beneath the shade of the structures; the radiometers simultaneously measured irradiance on the horizontal surface (HS) and then on vertical surfaces oriented toward the sun (VST-Sun) and the cardinal points (VST-North, VST-West, VST-South, VST-East). The UV protection efficiency was calculated according to the formula:

$$\text{UV protection efficiency} = 100 - \frac{\text{UVBEeryth shade}}{\text{UVBEeryth full sun}} * 100$$

The UV protection efficiency represents the percentage decrease of the radiation in the shade compared to that in the full sun for each surface orientation; it provides useful information for describing the protective role of the shading structure especially in the case of not negligible levels of radiation in the full sun.

Each set of measurements, approximately 8 minutes long for each shading structure, was composed of 6 simultaneous measurements in the shade and full sun (one for each radiometer position); each sequence was repeated 7 times for the beach umbrella and gazebo 1, once for "gazebo 2" and "gazebo 3" (around noon). Gazebos 2 and 3 were in the two bathing establishments adjacent to that of gazebo 1, not reachable with the electric cable of the radiometer, therefore taking measurements on gazebo 2 and 3 would have involved moving the entire radiometers-data logger system several times, also in periods of the day when solar radiation varies relatively quickly. We decided to obtain an evaluation of their protective effect in the maximum daily UV period when radiation was also more stable (around solar noon).

The radiometers were maintained at a height of about 1 m and the one in the shade was moved to avoid direct solar beam (always maintained in the shade), for this reason measurements were not possible very early in the morning and very late in the afternoon (before 8:30 and after 16:30) when the sun was particularly low above the horizon; consequently, data were representative for the portions of the body in the shade.

2.2. Characterization of UV protection offered by clothing

2.2.1. Material collection

Some T-shirts used by lifeguards were collected in the area. Different type of T-shirts were considered: generally red (only one light green), four in cotton and three in polyester, only one without sleeves. Some T-shirts were available both in both the used and new version.

2.2.2. UPF measurements

The UPF (Ultraviolet Protection Factor) defines the protection offered by a fabric from UV radiation. Among the existing classification systems, the Australian/New Zealand Standard (AS/NZS 4399:1996) was the first and is the most widely adopted [57]. A UPF of 15 is the minimum acceptable value for good protection, 25 for very good protection and 40-50 for excellent protection (Supplementary Table S2).

Fabric UPF and UVA transmission measurements were done according to Grifoni et al (2009) [58] using a UV-Visible single monochromator spectrophotometer UV-2600 (Shimadzu Corporation-Kyoto, Japan), equipped with an integrating sphere (ISR-240A Integrating Sphere).

3. Results

3.1. UV climatology in viareggio

Fig. 1 shows the climatology of UVI at solar noon and the cumulated daily $UVBE_{eryth}$ (in SED) in Viareggio.

In Viareggio, a typically Mediterranean solar UV radiation regime is evident, with a high or very high level from late spring to early autumn (Fig. 1).

3.2. Day's thermal comfort and radiative characterization and protective role of gazebos and beach umbrella

A beach lifeguard directly exposed to solar radiation for most of the day was also affected by heat stress conditions, ranging from moderate (from 6:45 to 8:30 and from 16:30 pm to 18:45) to strong (from 8:45 to 16:15) stress categories (Fig. 2). On the other hand, no thermal stress was observed, considering a lifeguard in shady conditions.

On HS, in the full sun condition, UVI reached the maximum value of 8.2 around solar noon and was constantly above 2 from 8:00 to 16:00 (Fig. 3A); in this condition, the daily integral of $UVBE_{eryth}$ was 4.8 kJ (about 23 MED or 48 SED).

The UV transmittances of different shading structures were measured to be 3%, 1%, 5%, and 0.2% for gazebo 1, gazebo 2, gazebo 3 and the beach umbrella, respectively.

In shaded conditions, under gazebo 1 (Fig. 3), the UV radiation on HS was significantly reduced, the maximum daily UV Index being close to 1; efficiency remains around 90% during the day (Fig. 3A). Considering the vertical surfaces, the maximum daily UVI on VST-North was around 1, while for all other orientations the maximum daily UVI was lower than 2; contrary to what was observed for HS, a very variable gazebo efficiency was observed. While for VST-Sun and VST-South (Fig. 3B and E) the efficiency was in the range 60–70% and 50–60%, respectively, for VST-West and VST-East (Fig. 3D and F) the efficiency was extremely variable during the day from 20% (early in the morning on VST-West and late in the afternoon on VST-East) to 70% (early in the morning on VST-East and late in the afternoon on VST-West). In the case of VST-North, the efficiency was relatively low (30–40%). However, in all these cases of low efficiency the UV radiation from the sun was low.

In Fig. 4 the UVI at noon (full sun UVI close to 8) and the protective efficiency of gazebos 2 and 3 are showed in comparison with that of gazebo 1. UVI under gazebos 2 and 3 and consequently their efficiency in blocking UV radiation were close to that of gazebo 1.

As for gazebo 1, also under the beach umbrella all UVI values were lower than 2 for all the surface orientations, but with a slightly higher UVI particularly on HS (close to 2). Concerning the

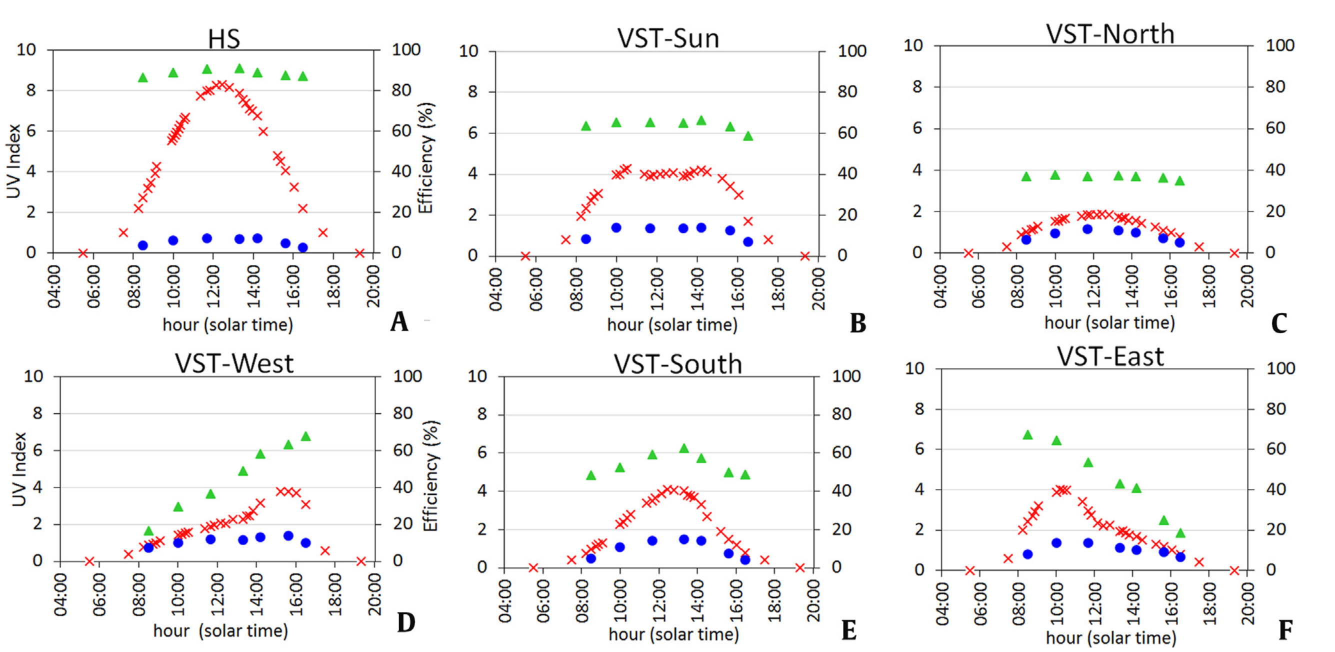

Fig. 3. UVI on horizontal surface (HS) and on vertical surfaces oriented towards (VST) the sun and cardinal points: UVI in full sun (cross), UVI under "gazebo 1" (circle) and protection efficiency (triangles).

daily trend of UVI, the considerations made for gazebo 1 are also valid for the beach umbrella (Fig. 5).

3.2.1. *Quantification of UV protection property of gazebo 1 in terms of SED*

The hourly and multi-hourly $UVBE_{eryth}$ (in SED) from sunrise to sunset in full sun and shading conditions, are shown in Table 1.

The maximum value in full sun was recorded over HS, 7.3 SED on an hourly basis and 27.32 SED over a 4-hour period. The presence of the gazebo significantly reduced the $UVBE_{eryth}$ on all differently oriented surfaces; on an hourly basis all the values were between 0.55 and 1.39, while considering the four-hour intervals the values varied between 2.20 and 5.15 SED with an efficiency between 32 and 91%.

3.3. *Clothing UPF*

For each analysed T-shirt, the fabric UPF and UVA transmission, together with other characteristics, are shown in Table 2. All the fabrics used resulted as having very good-excellent protection according to the standard AS/NZS 4399:1996.

4. Discussion

Outdoor workers, such as lifeguards, working in areas with high UV radiation level are exposed to an extremely high risk of sun related cancer [12,14,27,59,60] and concerning this the International Agency for Research in Cancer (IARC) [61] has classified UV radiation as carcinogenic for humans. In Italy skin cancer (KCs, but also actinic keratosis considered by some to be in situ SCC) are included in the list of occupational diseases compensated for in workers exposed to UV radiation by the Italian Workers' Compensation Authority, nevertheless occupational skin cancers in Italy are largely underreported [59].

Despite the seaside economic sector in Italy having a large number of workers (about 3.000 in the period March-April only in the Viareggio area), the UV radiation risk, also aggravated by heat stress conditions, is little known and underestimated and workers also revealed unsatisfactory sun protection behaviours [62].

On HS, under gazebo 1, the incoming radiation is exclusively composed of the component from the residual sky viewed and from that transmitted by the cover. The gazebo's efficiency on HS remains high and constant during the day. On vertical surfaces, the above mentioned components for HS should be increased accounting for reflection from the ground that can become relevant considering the highly reflective nature of sand. On vertical surfaces the efficiency is lower than on HS and varies greatly with the sun position and surfaces orientation [36]. This is mainly due to significant variations of the incident radiation in full sun than in the shade (where the values are anyway subject to small daily fluctuations). Concerning the reflective nature of sands, Liu et al [63] measured twice the biologically effective irradiance at ocular level on a beach surface compared to a grass surface, occurring at a maximum of a solar zenith angle of 40°.

Turner and Parisi (2018) [64], in a recent review, after realizing that only a limited range of studies empirically measured UV albedo or reflectance, concluded that whilst the study of the influence of albedo contribution to UV exposure is relevant, there is no study that has sought to correlate albedo or reflectance values with the actual increased UV exposure. From the literature a directly proportionally higher exposure to the albedo value does necessarily result, the role played by the orientation of the receiving surface, with respect to the reflecting one, being very important. However, it should also be remembered that

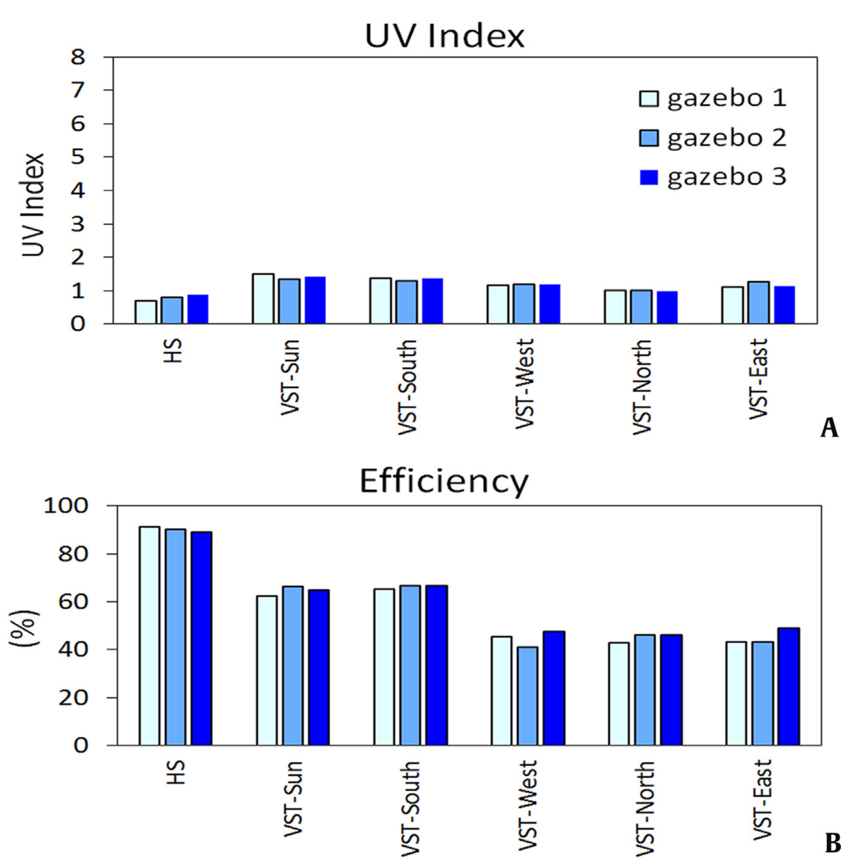

Fig. 4. UVI under gazebo 1, 2 and 3 (A) and protection efficiency (B).

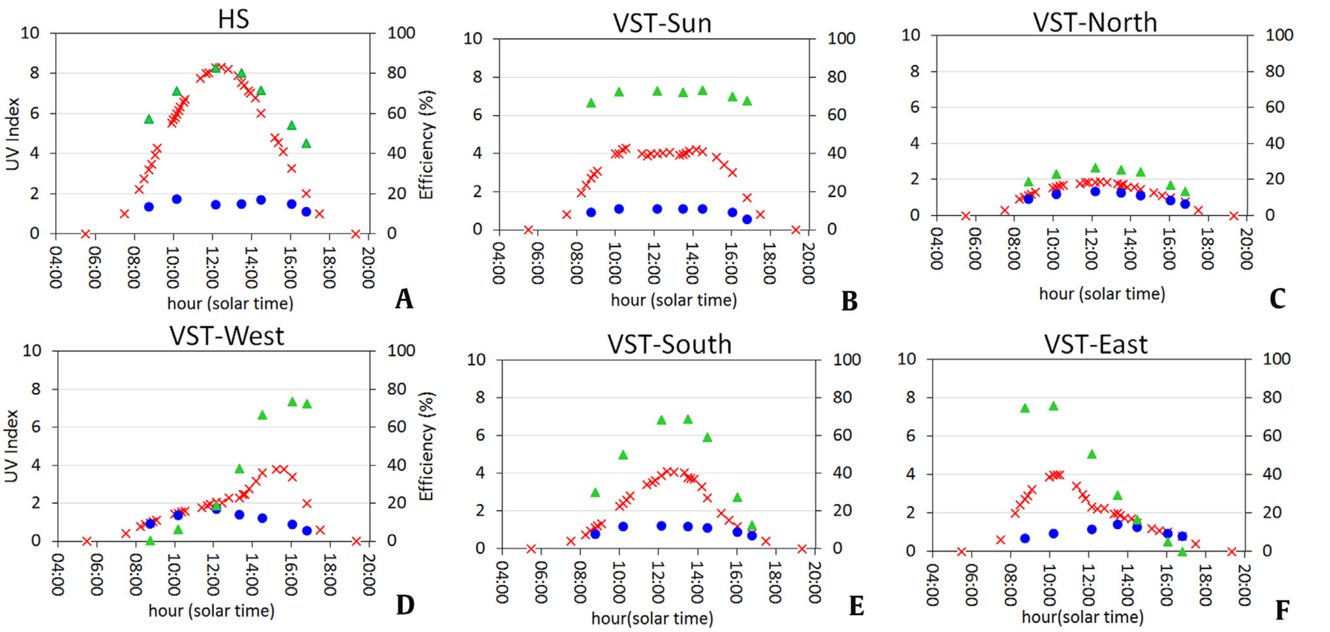

Fig. 5. UVI on horizontal surface (HS) and on vertical surfaces oriented towards (VST) the sun and cardinal points: UVI in full sun (cross), UVI under "beach umbrella" (circle) and protection efficiency (triangles).

different types of sand can have very different albedos [64] and this could have different impacts on the radiation in the shade.

The comparison between the three different gazebos, even if performed only at solar noon, showed no relevant differences; the higher transmittance of the cover of gazebo 3 was probably compensated for by its larger cover dimensions.

Considering the beach umbrella, the efficiency was on average slightly lower than that of gazebos, evident for HS, mainly due to its smaller cover surface; slightly higher efficiency than that of the gazebo 1 was temporarily observed for some orientations probably due to the presence of deck chairs and other beach umbrellas in the field of view of the sensor.

Results obtained for the umbrella were also very similar (at least for vertical surfaces) to those of previous measurements performed by the authors on another beach and using a type of umbrella with a different diameter [45]. In agreement with our

Table 1
At the top of the table, the hourly $UVBE_{eryth}$ (in SED) on horizontal surface (HS) and on vertical surfaces oriented towards (VST) the sun and cardinal points in full sun and under the shade of gazebo 1. In brackets the protection efficiency (%) of the gazebo. At the bottom of the table the same data for 8-hour and 4-hour intervals.

Time period (solar time)	Full sun						In shade					
	HS	VST:					HS	VST:				
		Sun	North	West	South	East		Sun	North	West	South	East
Hourly intervals												
5:30–6:30	0.18	0.09	0.09	0.09	0.09	0.09						
6:30–7:30	0.62	0.45	0.31	0.31	0.31	0.45						
7:30–8:30	1.48	1.48	0.71	0.63	0.67	1.53						
8:30–9:30	3.04	2.60	1.09	0.97	1.27	2.62	0.42 (86)	0.92 (64)	0.67 (38)	0.76 (22)	0.63 (50)	0.88 (66)
9:30–10:30	5.06	3.53	1.38	1.29	2.05	3.41	0.57 (89)	1.20 (66)	0.86 (38)	0.92 (29)	0.95 (54)	1.20 (65)
10:30–11:30	6.53	3.71	1.59	1.57	2.78	3.20	0.65 (90)	1.32 (64)	1.01 (36)	1.05 (33)	1.18 (58)	1.26 (61)
11:30–12:30	7.30	3.55	1.67	1.76	3.38	2.39	0.7 (91)	1.32 (64)	1.03 (38)	1.07 (39)	1.32 (61)	1.18 (51)
12:30–13:30	7.21	3.56	1.62	1.98	3.63	1.84	0.63 (91)	1.26 (65)	0.99 (39)	1.05 (47)	1.39 (62)	1.03 (44)
13:30–14:30	6.29	3.69	1.46	2.65	3.09	1.56	0.65 (90)	1.24 (66)	0.92 (37)	1.16 (56)	1.28 (59)	0.92 (41)
14:30–15:30	4.69	3.47	1.19	3.28	1.98	1.24	0.57 (88)	1.20 (66)	0.78 (34)	1.22 (63)	1.03 (48)	0.84 (33)
15:30–16:30	2.92	2.38	0.87	3.14	1.07	0.87	0.36 (88)	0.9 (62)	0.57 (35)	0.97 (69)	0.55 (49)	0.71 (18)
16:30–17:30	1.47	1.13	0.54	1.88	0.54	0.50						
17:30–18:30	0.61	0.43	0.21	0.49	0.21	0.26						
18:30–19:30	0.18	0.09	0.04	0.13	0.04	0.04						
Multi-hour time intervals												
All day	47.58	30.15	12.75	20.17	21.12	20.01						
8:30–16:30	43.04	26.48	10.85	16.64	19.25	17.12	4.47 (90)	9.36 (65)	6.85 (37)	8.19 (51)	8.27 (57)	8.00 (53)
10:30–14:30	27.32	14.50	6.32	7.96	12.88	8.98	2.58 (91)	5.14 (64)	3.95 (37)	4.33 (46)	5.15 (69)	4.37 (51)
8:30–12:30	21.93	13.39	5.72	5.59	9.47	11.61	2.28 (90)	4.76 (64)	3.59 (37)	3.80 (32)	4.05 (57)	4.52 (61)
12:30–16:30	21.10	13.09	5.13	11.05	9.78	5.51	2.20 (89)	4.59 (65)	3.26 (36)	4.20 (62)	4.22 (57)	3.47 (37)

Table 2
UPF, UVA transmission, and other characteristics of the fabrics used for the analysed T-shirt

T-Shirt	Age	Material	Colour	UPF	UVA transmission (%)
1	New Used	Cotton Cotton	Red Red	>50 40/>50	<5 <5
2	Used	Polyester	Red	40/>50	<5
3	New	Cotton	Red	>50	<5
4	New Used	Cotton Cotton	Red Red	>50 >50	<5 <5
5	New	Polyester	Red	25-30	>5
6	New	Polyester	Red	>50	<5
7	Used	Cotton	Light green	30/50	>5

results, Vejakupta and Udompataikul (2014) [65] verified that the protection of umbrellas with different canvas types and diameters (from 112 cm to 152 cm) were not statistically relevant probably because the sensors, on the vertical surfaces of manikins, mainly intercepted the reflected component from the ground.

Referring to Table 1, the gazebo's efficiency in blocking $UVBE_{eryth}$ was coherent with that described for the instantaneous UVI, with a not negligible radiation dose also in the shade.

Given that the recommended threshold limit value (TLV) for outdoor workers corresponds to 1-1.3 SED over a period of 8 hours [21,51,66] it is evident that also in the shade the limit is never respected in the four-hour intervals and sometimes not even in the case of hourly intervals. Referring to the MED thresholds for different phototypes, the hourly UV doses in the shade are always lower, while on a four-hour basis the UV doses in the shade are generally higher, at least on vertical surfaces and up to phototype IV, confirming the presence of a not negligible UV dose also in the shade, especially with a prolonged exposure.

Tizek et al (2020) [66] verified that, despite being protected by trees, the risk of Keratinocyte carcinoma (KC) for foresters was comparable to that of other professional groups concluding that shade alone may not provide sufficient protection. Ou-Yang et al (2017) [46] testing the UV protection of a beach umbrella and sunscreens, assessed that the former alone may not provide sufficient protection for extended exposure and that it is important to educate the public in combining multiple sun protection measures.

All the analysed T-shirts resulted as having very good-excellent protection even though they were not UV certified T-shirts. A wide range of UV protection can be reached using several types of natural or artificial fibres, dyed or not dyed with natural or artificial dyes, treated or not treated with specific UV protection additives; in fact, the protection offered by a textile is also a combination of additional factors such as its thickness/texture. Some studies have demonstrated that synthetic fibres, such as polyester, generally offer very good protection from UV radiation, but they are water-repellent and therefore uncomfortable to wear when temperatures are high [37,67]; in our case the relatively lower UPF was obtained for a polyester T-shirt probably because the fabric had a low fibre density.

In conclusion, shading structures must be considered an essential protection tool against both UV and heat-stress risks, which workers have to stay as long as possible, compatibly with the activities to be carried out, but not forgetting also to implement the other forms of protection including sun protective work clothing, sun protective hats, sunglasses and also sunscreen, as well as maintaining normal behaviours to avoid dehydration. According to previous considerations solar radiation guidelines for the prevention of risk from UV were approved by the Italian Technical Coordination for Safety in the Workplaces of the Regions and Autonomous Provinces, (available on https://www.portaleagentifisici.it/faq_explorer_ron.php?lg=IT). The guidelines were elaborated by the Physical Agents Thematic Subgroup of the Interregional Technical Group Prevention, Hygiene and Safety in the Workplaces in collaboration with Occupational and Environmental Medicine, Epidemiology and Hygiene Department, Italian Workers' Compensation Authority (INAIL) and Italian National Institute of Health (ISS).

Conflicts of interest

None to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2022.08.009.

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