EXPOSURE TO SOLAR UV RADIATION IN ITALY UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

ESPOSIZIONE ALLE RADIAZIONI UV IN ITALIA IN DIFFERENTI CONDIZIONI AMBIENTALI

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Abstract

The exposure to UV radiation was studied for the following relatively homogeneous targeted groups of people under peculiar environmental conditions: a) sunbathers (marine environment); b) skiers (alpine environment); c) winegrowers (rural environment).
A comparison among different groups/environments was carried out taking advantage of an easy-to-estimate and reliable exposure index, the Exposure Ratio (ER). In particular, for the members of the most populated group (skiers) the intra-group variability of individual ER values changed from day to day depending upon the sun exposure of the preferred ski slopes tracks. In the sunbathers case, the three different groups of people under study were not distinguishable based on ER values while in the case of winegrowers seasonal occupational activities as well as the somatic location of dosimeters appeared to be the leading factors influencing ER. All in all, in spite of its essentially physical nature, the ER parameter showed to be a valuable although indirect index of individual behavioural features.

Abstract

E' stata studiata l'esposizione ai raggi UV per i seguenti gruppi relativamente omogenei di persone in condizioni ambientali particolari: a) bagnanti (ambiente marino), b) sciatori (ambiente alpino), c) viticoltori (ambiente rurale).
E' stato realizzato un confronto tra i diversi gruppi / ambienti sfruttando un indice di esposizione affidabile e di facile stima, quale il rapporto di esposizione (ER). In particolare, per i membri del gruppo più numeroso (sciatori) la variabilità dei valori singoli di ER è cambiata giorno per giorno a seconda dell' esposizione al sole delle piste da sci utilizzate. Nel caso dei bagnanti, i tre diversi gruppi di persone in fase di studio non erano distinguibili in base ai valori di ER, mentre nel caso dei viticoltori le attività lavorative stagionali così come la localizzazione somatica dei dosimetri sembravano essere i fattori principali che influenzavano l'ER. Nel complesso, nonostante la sua natura essenzialmente fisica, il parametro ER ha mostrato essere un indice valido sebbene indiretto delle singole caratteristiche comportamentali.

Introduction

The Italian territory, spanning in longitude from 358° N (SE INCLUDIAMO LAMPEDUSA) to 46° N, is characterized by considerable large geographical and geomorphological variability, including altitude, climatic conditions and life-styles. Thus, the individual exposure to solar UV radiation depends upon a number of physical (ozone amount in the atmosphere, position of the sun in sky, atmospheric turbidity, cloud coverage, etc.) and behavioural parameters (attitudse towards sun exposure, occupational and recreational activity, use of protective tools such as sunscreens, etc.) which makes it difficult comparisonsto compare complicate the analysis of data collected by during thein different in field campaigns when comparing different sites of the national territory (1, 2). To overcome such difficulties, we decided to use rely upon a a parameter quite general index named Exposure Ratio (ER), that which is a relatively simple and straightforward estimate of the amount of the available UV radiation reaching human exposed skin (3, 4). The main advantage of such an approach relies on its robustness and reliability which may constitute a starting point both for further exploration of other individual effects of solar UV exposure and for the design of appropriate mechanistic interpretations underlying the observed effects.

To try and compare heterogeneous geographical and behavioural situations by a single quantifier of the UV radiation exposure, we use here data from field campaigns carried out by our resesarch team in an extended time period over targeted subjects in a marine, an alpine and a countryside environment. The data collection procedures are described in full detail elsewhere (5, 4, 3); here we compare and re-interpret the results in terms of ER, trying to extract the information of general interest and application out of the observed specific peculiarities.

An important unifying characteristic of such procedures is the systematic use of the polysulphone dosimetry, due to the intrinsic flexibility and reliability of this method which, since many years now, has been considered the 'gold standard' with respect to personal UV exposures (4, 6).

Methods

Useful quantitiesquantifiers Indicators of personal exposure

The UV band is not equally effective at any wavelength in producing a given biological response and a specific action spectrum is generally used to estimate specific biological responses to UV radiation (7, 8). The action spectrum for erythema in humans (9) has been widely employed in studies on personal exposures.

The most used quantitiesquantities indicators of the amount of solar UV radiation flux through human's body are:

i) the Personal Exposure (PE), related to the total amount of UV radiation reaching anatomical sites after weighting by an action spectrum over a specific time interval (10, 11);

ii) the Exposure Ratio (ER), a dimensionless parameter defined as the ratio between PE and the corresponding Ambient UV Exposure (AE). ER is dependent on the environmental exposure conditions and strongly related to individual attitudes and posture during exposure (3, 4, 10, 12). Thus, ER is especially useful in comparing different conditions and exposure times;

iii) the UVI (UV Index) a dimensionless parameter determined as the biologically weighted irradiance using the CIE (Commission Internationale de l'Eclairage) erythemal action spectrum (9), integrated up to 400 nm and divided by 25 mW m−2 (13). UVI values can range between 0 (during the night) and above 10 (in the tropics under clear skies and at noticeable high altitudes).

In the present paper, ER will be used to compare the relative influence of environmental conditions and individual behaviours on the personal exposure to solar UV radiation.

Polysulphone dosimetry

The polysulphone (PS) is a polymer whose optical absorbancy increases in the UV range when exposed to UV radiation. The polysulphone spectral response is similar to the erythemal action spectrum (6), which makes it suitable to quantify the erythemally effective UV dose received by an anatomical site .

PS dosimetry requires a careful determination of the calibration curve (10, 11, 15). This curve is obtained by exposing the PS dosimeters on a horizontal plane for specific time intervals and simultaneously measuring the AE using a calibrated instrument (broad-band radiometer or spectroradiometer). The curve can be parameterized by a coefficient, c, multiplying a cubic polynomial function (6, 16):

$$D = c\,(\Delta A + \Delta A2 + 9\Delta A3)$$

where D is the erythemal dose, expressed in kJm-2, and can be determined in situ or derived from the total ozone and the solar zenith angle, thus accounting for the local environmental conditions (15). The use of the above formula allows for the determination of PE for a chosen body site. The ratio between PE and with the corresponding AE provides gives the mentioned ER values.

Results

Data presented in three different peer-reviewed papers (respectively 5, 4 and 3) are here compared and re-interpreted in terms of ER, trying to find an explicative pathway through the main differences.

ER at the seaside (sunbathers, marine environment)

The field experiment concerning a marine environment was carried out on 27 May 2005 at Fregene (41.8°N, 12.2°E, 0 m a.s.l.), in a typical radiative scenario. Three groups of individuals were recruited:

1- already suntanned;

2- with no previous exposure - non-suntanned;

3- with an abnormally high sensitivity to their first UV exposure.

Each volunteer was equipped with a PS dosimeter attached to be allocated on to the chest and was asked to follow his/her ordinary sunbathing habits. Totally 37 volunteers took part to the campaign: 17 for group 1 (9 males and 8 females); 11 for group 2 (6 males and 5 females); 9 for group 3 (3 males and 6 females).

The results for PE, AE and ER, reported in Table 1 and Figure 1 in terms of averages and standard deviations, showed no significant differences (P=0.722) across the groups also in their ER median scores (0.20 for suntanned individuals, 0.17 for non-suntanned individuals and 0.19 for photosensitive individuals) although a high variability was observed due to the different postures (minimum is 0.09 for individuals mostly in motion and maximum of 0.42 for those mainly lying). The maximum ER values are higher than those reported in the World Health Organization (WHO report # 45) where it is mentioned that UV exposure can vary from 5% to 15% of total ambient UV radiation and for outdoor workers exposures can reach 20–30%.

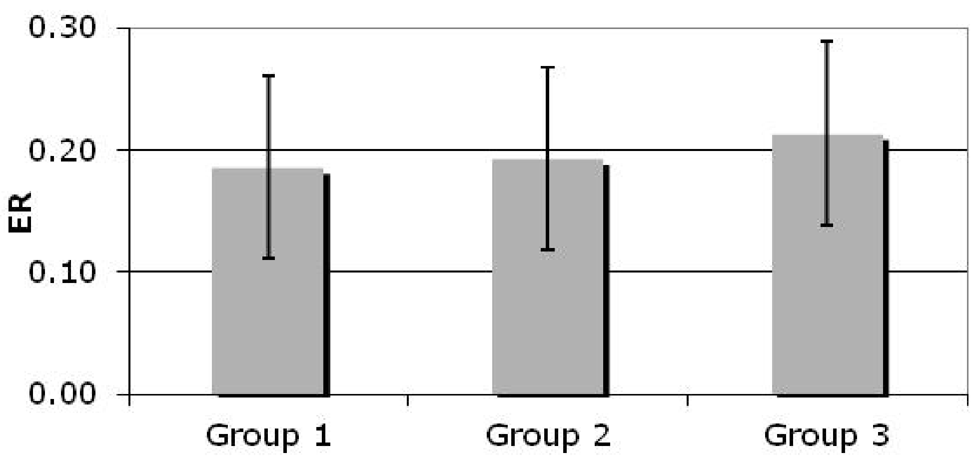
Table 1

PE, AE and ER in a group of sunbathers.

Results are given as median, minimum and maximum values. See the text for details.

	Suntanned (subgroup 1)	**Non suntanned (subgroup 2)**	**Photosensitive (subgroup 3)**
PE (kJ m⁻	0.26 (0.10-0.42)	0.24 (0.12-0.48)	0.20 (0.17-0.32)
AE (kJ m⁻	1.25 (0.75-1.47)	1.20 (0.73-1.47)	1.12 (0.62-1.47)
ER	0.20 (0.09-0.34)	0.17 (0.13-0.42)	0.19 (0.14-0.34)

Figure 1- *ER average and standard deviation values of ER in sunbathers*



ER on the mountains (skiers, alpine environment)

The skiers field campaign was carried out at La Thuile-Les Suches ski field (45.7°◦ N, 6.6◦° E, 2100 m a.s.l.), in Valle d'Aosta region, which has mostly ski slopes oriented towards east direction and chair-lifts and ski-lifts mainly oriented towards northwest-west. The campaign covered both a spring period (30 March–4 April 2006) and a winter one (29–30 January 2007) and involved 62 participants (31 instructors and 31 skiers): 47 males and 15 females with a median age of 44 years ranging from 20 to 66 years. There were 11 and 4 females among skiers and instructors respectively. A total number of 13 adults (6 instructors and 7 skiers) participated only in the winter campaign, 30 adults (19 instructors and 11 skiers) only in the spring campaign. There were indeed 19 participants (6 instructors and 13 skiers) in both seasons. Over the whole study period, 11 skiers and 14 instructors participated in one spring day, 13 skiers and 6 instructors in two spring days, 5 instructors in three spring days, 7 skiers and 6 instructors in one winter day. Taking into account both seasons, 9 skiers participated for a total of three study days (two days in spring and one in winter), 6 instructors and 4 skiers participated for a total of two study days. All skiers wore three dosimeters which were changed approximately every two hours in both campaigns. Ten instructors used two dosimeters and only two instructors wore the third dosimeter in spring. In winter instructors wore only one dosimeter during the time slot from 10:00 to 12:00 LT. Table 2 summmarizes the results for ER only, for each day of the spring field campaign.

Table 2

Seasonal changes of ER in skiers and ski-instructors.

Results are given as median, minimum and maximum values. See the text for detail

	Mar 1	**Mar 2**	**Mar 3**	**Mar 4**	**29 Jan**	**30 Jan**
Instructors	0.77 (0.46-1.20)	0.88 (0.59-1.34)	1.10 (0.68-1.25)	1.40 (1.22-1.72)		0.96 (0.29-1.46)
Skiers	0.85 (0.63 -1.18)			1.23 (0.92-1.42)	0.54 (0.42-0.70)	

ER in the countryside (winegrowers, rural environment)

The winegrowers field campaign was performed organised in three periods during the year 2005 at a rural site nearby Siena (43.3°N, 11.3°E, altitude 300 m a.s.l.) in the heart of the Chianti Classico region in the center of Tuscany. The first period was in spring (20–22 April 2005, activity consisting mainly of soil preparation, enrichment and pruning); the second period was in summer (12–13 July 2005, activity consisting in grape pruning and soil fertilization); the third period was in fall (11–12 October 2005, during the grape harvest). The study involved 32 adults (26 males and six 6 females) aged 18–60 years. A total number of 13 adults (three 3 females and 10 males) participated in the spring campaign, 21 adults (18 males and three 3 females) in the summer campaign, 17 adults (13 males and four 4 females) in the fall campaign. Three subjects participated only in the spring campaign, six only in the summer and eight only in the fall. Six individuals were involved in both spring and summer campaigns, five participated in both summer and fall campaigns. Over the whole period of study, only four workers (three 3 males and one 1 female) participated in all campaigns as they were the only workers in permanent position in the farm, the other workers being seasonal. The volunteers worked together in the same vineyard (about 100 m2) and were equipped with two PS dosimeters per day: one was attached to the left arm and the second to the back of the neck. The body areas were chosen to represent the posture they assumed during the activity. For each dosimeter a different ER was retrieved. Table 3 shows the results for PE, AE and ER referred to each season.

Table 3

Seasonal changes in PE, AE and ER of winegrowers' arm and neck.

Results are given as median, minimum and maximum values. See the text for details.

	Spring	**Summer**	**Fall**
PE (neck) (kJ m^{-2})	1.45 (1.05-2.07)	1.00 (0.71-1.79)	0.30 (0.18-0.36)
PE (arm) (kJ m^{-2})	1.03 (0.71-1.41)	0.59 (0.38-1.00)	0.20 (0.13-0.26)
AE (J m^{-2})	2.00 (1.50-2.37)	2.00 (1.84-2.31)	0.31 (0.15-0.32)
ER (neck)	0.72 (0.53-0.87)	0.50 (0.36-0.77)	1.00 (0.72-1.20)
ER (arm)	0.44 (0.30-0.60)	0.29 (0.19-0.43)	0.67 (0.42-0.89)

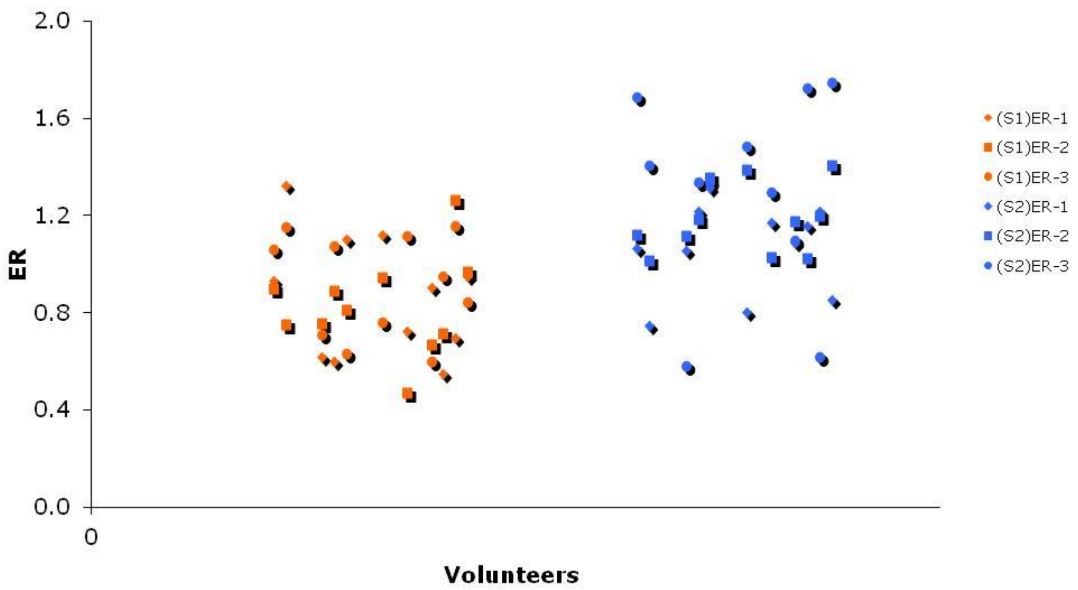
Discussion

In the case of sunbathers, The analysis of colorimetric parameters of the sun-exposed site for the three groups before and after exposure showed significant differences (P=0.023) between groups. Thus, the absence od significant differences in ER values points to the independence of this indicator from individual, somatic characteristics.

In the case of skiers, due to the lack of information on specific altitude during skiing, it was not possible to analyse the altitude dependency of ER. Personal doses should tend to increase with altitude and with combined factors (Rayleigh scattering, a smaller amount of tropospheric gases and albedo) and, consequently, an increase of ER could be observed. It should be noted, in addition, that individual body posture, repetitive movements during the activity, and individual positions related to the sun, can be also responsible of high variability of ER. The dose received by the specific anatomical location (in this study the forehead) also depends on the activity index i.e. the proportion of time spent in the sun. This suggests that the difference in ER values of the very same individuals observed in two spring days (Figure 2), could be very probably ascribed to the different features of the preferrred skiing tracks chosen in those days, that is, ultimtely, to different behavioural attitudes.

Figure 2 - *ER values of skiers in two close spring days.*

The same 14 individuals were checked for ER values in the same three consecutive time slots of 2 hours each of Mar31 (S1) and Apr(4). Diamond, square and circle shapes refer to the three time slots for each individuals.



In the case of winegrowers, The measured ERs are consistent with those found in other studies on outdoor workers even if our results are higher in some cases. However, a direct comparison is difficult to make because of the variety of anatomical sites considered and of the different postures related to occupational activities. Moreover, in some studies the percentage of ambient dose is calculated on an annual rather than on short-term basis. The large variability of ERs found among the above studies is noticeable, and ultimately reflects the impact of the diversity of exposures related to posture, orientation and movement during the different season-dependent activities. This insures specific interest to our results, concerning well defined body sites and the highly season-dependent working performance of winegrowers. In any case, to allow comparison among different studies, the development of guidelines and adoption of a standard protocol appears necessary and requires future work.

Conclusions

In spite of the wide heterogeneity of human and environmental parameters studied in the three above described cases, a wise and appropriate use of the Exposure Ratio (ER) quantifier of UV personal exposure allows to dissect out the relative influence of environmental (physical) and personal (behavioural) parameters in the personal response to UV radiation, as shown by:

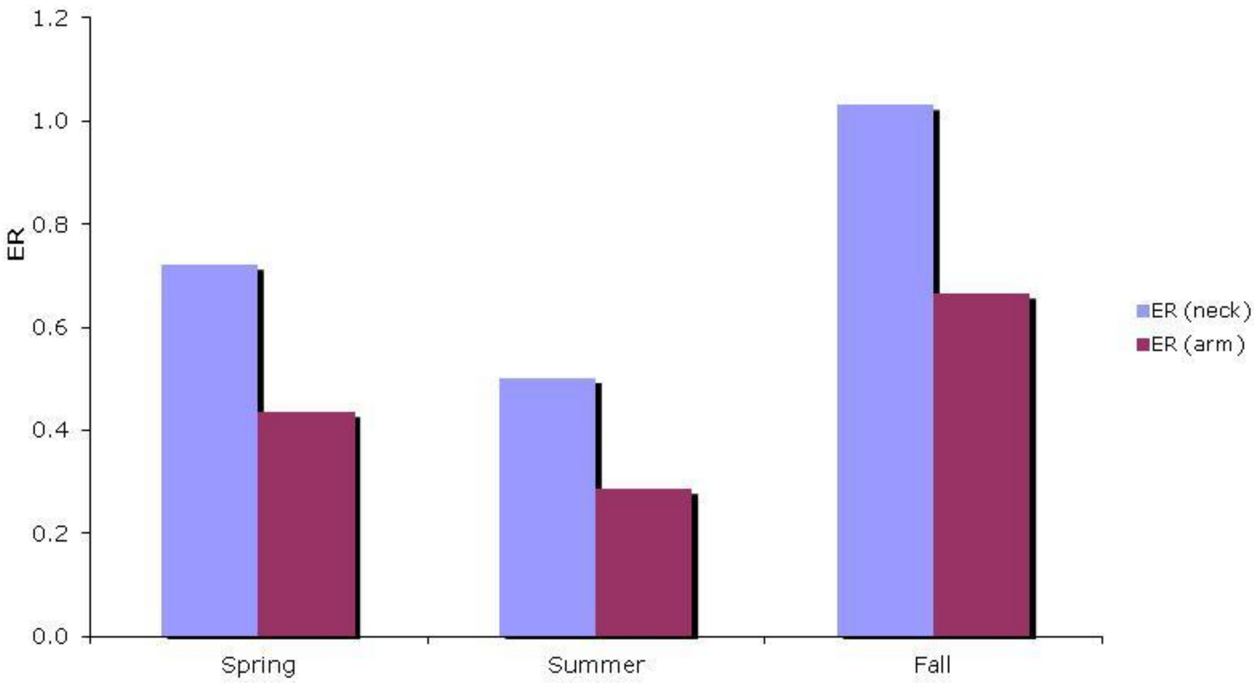
i) the lack of any significant difference in the ER median values of three groups of sunbathers, sharing the same observation time and environment, and characterized by pretty similar personal behaviour;

ii)the significant difference observed in the ER of the very same individuals (skiers) as a consequence of choosing different environments for their physical performance in the same period of time;

iii)the seasonal changes of ER of different body sites of winegrowers, directly reflecting their season-related working activities.

Figure 3 - *Seasonal changes ER of winegrowers' arm and neck*.

Blue and purple colors refer to nech and arm, respectively, and the results are given as median values. See the text for details



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List of acronyms used in the text

AE: Ambient Exposure

CIE: Commission Internationale de l'Eclairage

ER: Exposure Ratio

PE: Personal Exposure

PS: Polysulphone

UV: Ultraviolet

UVI: Ultraviolet Index

WHO: World Health Organization

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