REDUCING HUMAN EXPOSURE TO SOLAR ULTRAVIOLET RADIATION

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Abstract

Methods for reducing human exposure to solar ultraviolet radiation may not provide the expected degree of reduction in exposures with resultant undesirable effects which could be harmful. This paper examines the use of strategies for campaigns against skin cancer. It was shown that outdoor activities conducted before 10:00 am or after 3:00 pm may reduce the exposure by about 50 %. The choice of UV-protective clothing should look for fabrics with high weight and compact weaving. Hats with a brim size up to 12 cm could reduce the exposure to less than 10 % of the ambient radiation on the forehead only. The protection of the hat for the lower part of the face is negligible (less than 10 % reduction in exposure). A flat shade-structure reduces the exposure to about 30 % of the natural ambient radiation at a height equal to the smallest dimension of the shade-cloth. In a greenhouse, the shoulder of a gardener could receive a cumulative exposure of 17 MED over a fortnight if he works 2 hours per day, for 5 days in a week. A well planned strategy using a combination of protective methods can minimize the level of exposure to harmful solar radiation.

Introduction

Sunscreen has been used for reducing human exposure to harmful solar ultraviolet (UV) radiation. For consistent applications in our daily life it could be uneconomical and inconvenient. Recently, it has been suggested that the use of sunscreen may be associated with an increased risk of melanoma (Westerdahl et al 1995). Other methods for protection against the harmful effects of UV on human skin have been proposed by a number of authors (Foot et al 1993, Diffey, Cheeseman 1992, McGee and Williams 1992, Standford et al 1995, Wong 1994). These methods may be summarized as follows:

- Restricted exposure time,
- Clothing,
- Headwear,
- Shade structures, and
- Protective enclosures.

The use of these methods indeed would reduce the level of exposure but it is essential that these methods are used with sufficient understanding of scientific data. This paper aims to clarify these issues using data collected by the author in the past fifteen years.

Materials and Methods

Measurements of exposure to solar UV

Polysulfone dosimeters (Diffey 1989) were used to measure the personal exposure to erythema UV radiation. These dosimeters were calibrated against a UV-spectroradiometer with the calibration data traceable to the national standard (Wong et al 1995). The dosimeter in a form of a film badge with a dimension of about 2 cm x 2 cm was attached to a selected anatomical site of the body surface. The exposure usually took less than one hour in summer. Ambient UV radiation was recorded continuously with a UV monitoring station. The UV station comprises of a UV Biometer (manufactured by Solar Light Co., Philadelphia, USA) connected to an automatic data logger. The detector in the station was periodically calibrated simultaneously against the calibrated spectroradiometer.

Clothings

The measurements of the UV-transmittance through clothing were consistent with the method described in the Standard Australia publication (Standard Australia 1996). A spectroradiometer fitted with an integrating sphere was used for the measurement. Fabric samples were glued to metal rings and placed in direct contact with the aperture of the spectroradiometer. The spectral transmittance, T_λ, which is the ratio of the transmitted irradiance to the source irradiance at the wavelength λ was determined. For assessing the protection of clothing, the concept of the ultraviolet protection factor (UPF) is used. It is defined by the following equation

$$UPF = \frac{E_{eff}}{E'} = \frac{\sum_{290}^{400} E_\lambda \times S_\lambda \times \Delta\lambda}{\sum_{290}^{400} E_\lambda \times S_\lambda \times T_\lambda \, \Delta\lambda} \qquad (1)$$

where E_λ is the relative erythema spectral effectiveness (CIE 1987), S_λ is the solar spectral irradiance and Δλ is the wavelength step.

Model and human exposure

Protective devices such as hats and shade structures, were assessed using both headforms and human volunteers. Headforms were set up on turntables driven at approximately 1 revolution per minute. An axle and pin arrangement allowed the heads to be tilted at selected angles. These headforms were used to simulate human activities. For measurements in the sun, one headform was used as a control. Protective devices were applied to the other headforms. Polysulfone dosimeters were attached to selected sites for measurement of exposure. Human exposure programs were also carried out to provide data to validate model experiments.

Protective devices

Protective devices selected for the test included hats, shade structures and enclosures. Hats of different sizes were studied using both humans and headforms. Shade structures studied were limited only to the type using shade-cloth. Enclosures selected for the study were the ones with transparent walls and roof. The exposure to filtered UV were compared to that in the natural environment.

Results

Data obtained from our laboratory in the past fifteen years were selected for discussion with respect to the categories listed in the Introduction section.

Restricted exposure time

In Australia, people have been advised to stay away from the sun between 10:00 am and 3:00 pm by the anti-cancer agents. A typical example of the result on ambient radiation measured under a clear sky in Brisbane is provided in Table 1. In the second column, the erythema irradiance is given in μWcm^{-2}. The variation may be attributed to the time and seasonal variation. No effect of the cloud or the atmospheric aerosol content was taken into account.

Table 1 Ambient Radiation Under a Clear Sky in Brisbane

Time of the day	Erythema irradiance (μW cm^{-2})
9:00 - 10:00 am	10 - 20
Noon	30 - 40
3:00 - 4:00 pm	10 - 20

While it is recognizable that the irradiance peaks at noon (mean = 35 μW cm^{-2}) the level outside the restricted time domain (mean = 15 μW cm^{-2}) is significantly high. If the public believes that the time outside the restricted time domain is safe for sun bathing then an exposure of one hour between 9 - 10 am or 3 - 4 pm would be about 54 mJ cm^{-2} which is equal to 2.7 MED[a] .This is equivalent to about a 20 minutes exposure to the mid-day sun. Thus, emphasis must be made to warn the public of the danger outside the restricted period.

Clothing

Clothing has been tested for protection (Ultraviolet Protection Factor) against harmful UV (Roy et al 1988, Robson and Diffey 1990, Zhang et al 1997). A summary of the results for selected light-weight fabrics is presented in Table 2. Three types of materials: cotton, polyester cotton (poly-cotton) and polyester viscose (poly-viscose) were tested. The Table provides the values of UPF in the fifth column. Also included in the Table are the information about the fabric: the warp (in the second column), the weft (in the third column) and the weight per unit area (in the fourth column).

Table 2 Ultraviolet Protection Factor (UPF) for Selected Fabrics

Material	Warp*	Weft**	Weight (kg cm^{-2})	UPF
Cotton	101 - 110	70 - 99	1080 - 1280	8 - 20
Cotton	46 - 75	43 - 67	1410 - 1440	8 - 10
Cotton	88 -93	72 - 75	900 - 1040	4
Cotton	46 - 93	43 - 75	640 - 700	3
Poly-cotton	107 - 110	76 - 91	1010 - 1040	17
Poly-cotton	88 - 115	74 - 76	630 - 800	6 - 7
Poly-viscose	50	45	2140	20

*The warp is the number of threads in 2.5 cm of fabric along the length of the fabric.
**The weft is the number of threads in 2.5 cm of fabric along the breadth of the fabric.

An inspection of the above table provides a set of rules of thumb to assist the users in the selection of clothing fabrics for UV-protection, namely:

- Heavier materials, i.e. higher values of the weight, provide better protection (higher values of UPF)
- Greater warp and weft block more harmful UV

It should be noted that the fabrics in a wet condition could decrease the value of UPF by up to 150% (Zhang et al 1997)

Headwear

Hats have been promoted widely as a protective device for solar UV. The well known slogan "*Slip , Slap, Slop*" advises the public that during outdoor activities people slip on a shirt, slap on a hat and slop on some suncream for protection against harmful solar radiation. The message on the use of the hat could be misleading. The results of the tests on the hats scatter over a rather wide range. However, it is possible to draw some general conclusions from the data. A comparison of the level of exposure to the facial sites protected by the hat to that without protection can be made by determining the UPF. A similar formula as given in Eq. (1) can be used except that the spectral transmittance , T_{λ}, is replaced by the ratio of the exposure with the hat to that without the hat. In Table 3, the results of the test for the head in the upright position are presented. The UPF's given in the Table are divided into three facial

[a] 1 MED is taken to be equal to 20 mJ cm^{-2} (Diffey, 1992)

zone. These zones identified in the first column include the upper zone, the mid zone and the lower zone. The upper zone covers the area above the eye level. The mid zone includes the area between the eye and the lip. The lower zone is the area below the lip. For the two brim sizes (the first row) presented in the Table, the values of UPF are lying in the range between 4 and 17 for the upper zone. These correspond to, respectively, an exposure of about 25 % and 6 % of the amount of radiation falling on an unprotected face. The protection for the mid zone is less than 4 and the protection for the lower zone virtually does not exist. Thus, slapping on a hat should be supplemented by the application of suncream to the mid and the lower zone of the face if the outdoor activity is going to be substantially long.

Table 3 Ultraviolet Protection Factor (UPF) for Selected Hats

Brim size of the hat	6 - 8 cm	10 - 12 cm
Upper zone of the face	6 - 17	4 - 10
Mid zone of the face	1- 4	2 - 4
Lower zone of the face	1	1

Shade structures

The use of shade also provides a false sense of protection because the effect of scattered radiation can increase the level of exposure underneath the shade structure. Tests made on a horizontal plane suggested that the exposure at the center of the flat shade-structure increases as the height of the plane decreases. Using the ratio of the smallest dimension of the shade-cloth to the height, WH, the level of exposure at a value of WH = 1 is about 35 % of the unprotected level. Translated in terms of UPF, it is about 2.8. Under a clear sky, the erythema irradiance of the ambient radiation in summer is about 4 MED h^{-1}. For a child in a playground sheltered by a shade structure of about 1.6 m high, in one hour, the child in the upright position will receive more than one MED to the shoulder.

Protective enclosure

Protective enclosures with solid walls and roof present a safe block for harmful solar radiation. Measurements of the transmittance of erythema irradiance through perspex (4.2 mm thick) and glass (1.3 - 6.3 mm thick) yielded results ranging from 0.52 % to 1.04 %. These transparent barriers filter out most of the solar radiation in the UVB waveband (290 -320 nm). Due to the high flux of the UVA waveband in sunlight, the level of exposure in an enclosure with these transparent barriers is not negligible. According to Parisi and Wong (1997a), the erythema exposure to a horizontal plane within a glass enclosure recorded on a clear spring day (average ambient irradiance was less than 2 MED h^{-1}) over a 6 hour period is 17 mJ cm^{-2} or 0.85 MED. There is a tendency to stay in an enclosure for a longer period of time than in the outdoor environment. For example, a gardener may work 2 to 3 hours in a greenhouse for 5 days in a week as compared to two hours leisure on the beach for a weekend every fortnight. Then in a fortnight, the shoulder of the gardener would exposed to more than 17 MED in the greenhouse while the exposure received on the beach would be less than 4 MED h^{-1}. In a paper (Parisi and Wong 1997b) to be presented in this conference, there are detailed discussions to compare the exposure of filtered radiation to that of unfiltered radiation for some scenarios.

Conclusion

The methods for campaigns against skin cancer include the use of:

- sunscreen
- restricted exposure time,
- clothing,
- headwear,
- shade structures, and
- protective enclosures.

The application of sunscreen could be expensive, inconvenient and difficult. An exposure of one hour duration to solar ultraviolet radiation before 10:00 am or after 3:00 pm was about half of that between 10:00 am and 3:00 pm. Clothing fabrics of higher values of the weight per unit area, greater warp and weft block more harmful UV. Hats with brim sizes of up to 12 cm can provide a maximum value of UPF about 17 for the forehead but the UPF value for area below the lip is unity. In the case of the shade structures, a flat shade-cloth with the dimension equal to the height could reduce the exposure to a horizontal plane to about 35 % of the natural ambient radiation. An estimate of the exposure to the shoulder of a gardener, who works in a greenhouse 2 hours per day for 5 days per week, yields a cumulative value of 17 MED per fortnight.

These results suggest that the use of protective methods for reducing harmful solar radiation must be carefully planned. A combination of protective methods can be selected to optimize the benefit. For example, in the mid-day a sunscreen with an SPF (sun protection factor) of 15 passes to the body an exposure of about 7 % of the ambient radiation . If the exposure takes place before 10 am or after 3 pm with the cover of an umbrella in addition to the application of the sunscreen, the shoulder part of the body would receive a protection factor equivalent to an SPF of about 70. Namely, the exposure to the shoulder is reduced to about 1 % of the ambient radiation.

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