Dosimetric Investigation of the Solar Erythemal UV Radiation Protection Provided by Beards and Moustaches

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Short title: UPF Provided by Beards and Moustaches

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Abstract

A dosimetric technique has been employed to establish the amount of erythemal UV radiation protection provided by facial hair considering the influence of solar zenith angle (SZA) and beard/moustache length. The facial hair reduced the exposure ratios to approximately one third of those to the sites with no hair. The variation of the exposure ratios over the different sites was reduced compared to the case with no beard. The ultraviolet protection factor (UPF) provided by the facial hair ranged from 2 to 21. The UPF decreases with increasing SZA. The minimum UPF was for the 53-62^o range. The longer hair provides a higher UPF at the smaller SZA, but the difference between the protection provided by the longer hair compared to the shorter hair reduces with increasing SZA. Protection from UV radiation is provided by the facial hair, however it is not very high, particularly at the higher SZA.

Introduction

The introduction and wide spread use of the ultraviolet index (UVI)[1] as a means of forecasting the erythemal UV radiation (UVR) is a useful tool for informing the public. The UVI provides the intensity of the erythemal UVR on a horizontal plane. The risk of skin cancer is related to the UVR exposure to anatomical sites[2]. In order to understand the solar UVR environment for humans during normal daily activities and using a variety of protection strategies, monitoring of personal UVR exposures is important. To evaluate these exposures to human anatomical sites, measurement techniques based on thin film dosemeters[3-6] and electronic dosemeters[7,8] have been developed.

The risk of UVR damage as examined in this paper is primarily a scientific inquiry, but with underlying themes in public and individual health. Considering that Australia has one of the world's highest incidences of UVR related conditions and illnesses[9], the risks of UVR damage to health continue to be downplayed and in many instances rejected by at-risk sections of the population. More scientific inquiry is needed to better understand the UVR exposures in different circumstances to help bring the facts to the attention of the general public. The research in this paper will contribute to the understanding of exposures to humans but in a way that has not been investigated previously.

A report carried out by the European Agency for Safety and Health at Work included reference to UVR having a cumulative effect on the person, in that the greater the exposure to UVR the more sensitive they become[10]. This finding suggests there is considerable merit to any strategy that might limit exposure in the first instance. Reference was made in an earlier study of solar UVR protection from human head hair[11], in addition to existing UVR minimization strategies, including the use of hats, shade, clothing and sunglasses[12] and this study serves a similar purpose in exploring the additional protection provided by facial hair.

From a workplace health and safety perspective, any other strategy that might have the benefit of adding to the inventory of UVR minimization options, especially where a substantial portion of the working population is employed in outdoor occupations[11], is worthy of careful consideration. In an increasingly multicultural society such as Australia, which includes increasing numbers of persons born overseas where normal grooming norms dictate how facial hair is expected and normal upon entering maturity, one might reasonably expect that such groups will help to reduce the overall incidence of skin cancers and other occupational illnesses brought about by exposure to UVR.

However, while facial hair for males has enjoyed periods of popularity through the last hundred years or so, Komarova[13] suggests that trends in contemporary fashion are having the effect of reducing the appeal of facial hair for men in many professional occupations. It follows where fashion is a major determinant of whether or not facial hair will be worn, persons outside the professional occupations will also make conscious decisions about the relative merits of facial hair. This study may help to inform persons about the possible health implications of removing facial hair, with particular reference to UVR damage to exposed skin.

Various researchers[11,14] have noted that one of the more likely functions of head hair is the protection of skin from UVR related harm. An extension of this argument is that the greater the extent of hair growth over the parts of the body which are exposed to UVR, the greater is the level of protection. This paper reports on a dosimetric investigation of the amount of erythemal UVR protection provided by facial hair. In this investigation, the influence of SZA and beard/moustache length on the level of protection to normally exposed surfaces of the face is studied.

Materials and Methods

Ultraviolet Protection Factor

The ultraviolet protection factor (UPF) was determined by comparing the solar erythemal exposures[15] to the facial sites of upper left lip, upper right lip, upper right jaw, upper left jaw, mid right jaw, mid left jaw, lower right jaw, lower left jaw and chin compared to that at the same sites underneath a beard and moustache. The following was employed to calculate the ultraviolet protection factor at each site, UPF(s)[11]:

$$UPF(s) = \frac{UV_{ery}(s)}{UV_{ery}(p)} \qquad (1)$$

where $UV_{ery}(s)$ is the erythemal UVR exposure for each of the sites and $UV_{ery}(p)$ is the corresponding erythemal UVR exposure to the same site for the same time period and conditions under the beard/moustache.

For each of the facial sites, the exposure ratios ER(s) were calculated as the erythemal exposures at each site compared to those over the same period to an unshaded horizontal plane[16]:

$$ER(s) = \frac{UV_{ery}(s)}{UV_{ery}} \times 100\% \qquad (2)$$

where UV_{ery} is the erythemal UVR exposures on an unshaded horizontal plane.

The UPF was investigated at each of the sites by employing three upright adult life size manikin head forms (supplier, Apex Models, Brisbane) that were all exposed to solar radiation on a platform rotating at approximately 1 revolution/minute (Figure 1). One headform was deployed as the control with no facial hair attached and the other two were deployed with each of the short and the long hair beard and moustache respectively (supplier Creative Hair Products, Melbourne) attached to each manikin headform and over the dosemeters deployed at each of the facial sites. The colour of the hair was dark brown and the range of the hair lengths at each of the sites is provided in Table 1. Although, the angle of the head is not always upright during normal daily activities, this upright stance has been employed as one case of the head angles during normal activities.

The erythemal UVR exposures to each of the sites were measured for solar zenith angles (SZA) encountered over the year at the sub-tropical site of Toowoomba (27.6^o S, 151.9^o E), Australia. The data were collected in the majority of cases for relatively cloud free days. However, for a small number of cases some cloud formed after the measurements were started, with the largest amount of cloud being 4 to 5 okta as estimated by observation. The measurements were grouped into the five SZA ranges of 23.0-29.0^o, 40.8-42.5^o, 50.1-51.6^o, 52.6-62.9^o, and 59.0-67.7^o. This range of SZA provides results relative to latitudes that encounter SZA within the range of 23 to 67.7^o and are thus applicable to a range of global locations.

Dosemetry

The erythemal UVR exposures transmitted through the facial hair to the skin were measured with polysulphone dosemeters[17] placed at the following facial sites: upper left lip, upper right lip, upper right jaw, upper left jaw, mid right jaw, mid left jaw, lower right jaw, lower left jaw and chin. Dosemeters were employed to measure the UVR exposures as they provide an advantage of enabling simultaneous measurements at multiple exposure sites over a period of time. The dosemeters were miniaturized for this application, with the polysulphone film being adhered to 15 x 10 mm flexible frames consisting of a 6 mm diameter clear aperture[18]. The polysulphone dosemeter film was approximately 40 μm thick and cast in thin film form at the University of Southern Queensland, Australia. The pre-exposure and post-exposure optical absorbance of the dosemeters was measured at 330 nm in a UV spectrophotometer (model UV1601, Shimadzu Co., Japan)

The sequence for the deployment and retrieval of the dosemeters under the beards/moustaches was to: attach the dosemeters to each of the sites on the headform while indoors; attach the respective beard/moustache over the dosemeters while ensuring that the placement of the dosemeters was not disturbed and the beard/moustache hairs were reasonably evenly distributed; and deploy the headforms outdoors on the rotating platform for the exposure period. Each of the sets of dosemeters were exposed for a period of one hour, with the exception of the dosemeters for the 23^o-29^o SZA range which were exposed for two hours. Dosemeters were removed from the manikin headforms following exposure and stored in a light proof container for a period of at least 24 hours to allow for the post exposure polysulphone dark reaction[19].

The dosemeters were calibrated against an erythemal UV meter (model 501 Biometer, Solar Light Co., PA) recording the erythemal UVR exposures for every five minutes. This instrument was calibrated to a UV spectroradiometer (Bentham Instruments, UK)[20] with calibration traceable to the NPL standard and wavelength calibrated to the spectral lines of a mercury lamp. The UV spectrum measured with the spectroradiometer in 0.5 nm increments was weighted with the erythemal UV action spectrum[15]. This provided the erythemal exposure in units of Joules/m^2 which were in turn divided by 100 to convert to Standard Erythemal Dose (SED)[21]. A calibration of the dosemeters was undertaken for each season of the measurements. The ER(s) and UPF(s) at each facial site were subsequently calculated following the pre-exposure and post-exposure optical absorbance measurements of the dosemeters and the respective calibration curves.

Results

Erythemal UVR exposures over a one hour period for each of the facial sites for the case of no facial hair averaged over the five SZA ranges and the case of facial hair averaged over the five SZA ranges for the results taken with the two different beard lengths are shown in Figure 2. The error bars are the standard deviation of the data. These results are presented for each of the sites for the range of SZA from 23^o to 68^o. This SZA range is a notable factor affecting the range of exposures shown by the standard deviation. For the no facial hair case, the range of exposures for the one hour period is 0.32 to 3.8 SED in comparison to the range over the same period of 0.03 to 0.48 SED for the exposures under the facial hair. Exposures measured under both lengths of beards for each one hour exposure period were significantly lower ($P<0.05$) apart from measurements made to the upper lip in the 23^o-29^o SZA range. Measurements made to the upper lip in the 23^o-29^o SZA range also recorded the largest no beard exposure of 3.8 SED.

The exposure ratios expressed as a percentage with respect to a horizontal plane in full sun averaged over all of the SZA for each of the sites and for the cases of no beard, short beard and long beard are provided in Figure 3. The error bars are the standard deviation of the data. Some of the range of these error bars is attributable to the spread of values due to the recording of data for the different SZA. For the case of no beard, the highest average ER is 40% at the upper lip site with the lowest being 19% at the mid jaw site. In comparison, for the cases of a beard, the highest ER is 12% for the short beard at the chin site and the lowest is 4% for the long beard at the mid jaw site.

Figure 4 provides the solar erythemal UVR exposures in units of SED for a period of one hour averaged over each of the facial sites for the cases of no, short and long facial hair for the five SZA ranges from 23^o to 68^o. For the no beard case, the exposures reduce with increasing SZA from 1.4 SED to 0.5 SED for the one hour period. This is in contrast to the exposures under the beard where the slightly higher exposures of 0.3 SED for the one hour period are experienced for the SZA range of 53^o to 63^o. A possible explanation for this is that at the higher SZA, the direct component of the UVR is incident to the facial sites at angles that are closer to the normal and so possibly may result in a higher transmission through the beard.

The protection factors averaged over each of the facial sites for the short and long facial hair for each of the five SZA ranges are given in Figure 5. The UPFs range from 2 to 9.5 for the short beard and 2 to 21 for the long beard. For both hair lengths, the UPF decreases with SZA to the 53^o - 63^o range. The influence of the longer beard is more pronounced, particularly at the smaller SZA of less than 30^o.

Discussion

This paper has presented a dosimetric investigation of the solar erythemal UVR protection provided by beards and moustaches. The use of dosemeters in the research enabled simultaneous multi-site measurements that would be difficult and expensive to achieve with an instrumental approach to the measurement of the UVR exposures at the facial sites under the beards and moustaches. The application of the miniaturized polysulphone dosemeters in this research allowed deployment under the facial hair. This is the first investigation of the erythemal exposures to the skin under facial hair and the resulting protection factors that are provided.

The facial hair reduced both the amount of erythemal UVR exposures to the facial sites under the beards and the moustaches. For the case with no facial hair to these sites, the average exposure of 1.6 SED over a one hour period was in excess of the daily UVR exposure limit that is recommended in the occupational exposure to UV Radiation Protection Standard[22]. The facial hair reduced these exposures and consequently would extend the time taken to exceed the recommended exposure limits. The exposures varied with the different facial sites, with the highest exposure being to the upper lip. A possible explanation for this higher exposure is that as shown in Table 1, the length of the hair to the upper lip is up to half of that to the other facial sites.

The exposure ratios to the facial sites covered with hair were approximately one third of those to the sites with no hair. The amount of variation of the exposure ratios over these sites for both cases of long and short hair compared to the case with no beard is less than that with no beard. This is likely attributable to solar radiation being blocked by the presence of facial hair and as a result reducing the influence of the variation in orientation and inclination on the UVR exposures.

The UPF for the facial hair ranged from 2 to 21. This is comparable in magnitude to the UPF range of 5 to 17 provided by human head hair[11]. The small differences are possibly due to differences in the fall of the hair and also differences in the hair length. The UPF varies with SZA with the minimum UPF in the 52.6-62^{o} range. Although the UPF provided by the longer facial hair is higher, the difference between the protection provided by the longer hair compared to the shorter hair reduces with increasing SZA. This may be explained by the direct UVR at the larger SZA being incident at an angle that is closer to normal incidence with respect to the drop of the facial hair, resulting in a consequent reduction in the influence of hair length. The consequence is that less protection is provided by the facial hair for this SZA range. This change of the UPF with SZA is opposite to that for head hair where the UPF increased with higher SZA[11]. Similarly, for the head hair, the longer hair provided a lower UPF than the shorter hair.

Daily exposure limits to UVR have been provided as recommendations in the Radiation Protection Standard[22]. These are for exposures to the skin and any protection provided by facial hair will extend the time to reach these exposure limits for the parts of the face under the hair. However, any possible extension of the time exposed to UVR due to the fact that the facial hair is extending the time to reach the exposure limit for those parts requires the implementation of other protection strategies to the uncovered skin unprotected by a beard or moustache on the face. Furthermore, the average UPF provided to facial sites for both the shorter hair and for the longer hair for SZA greater than 30^{o} is less than 10 with cases where it is less than 5. Although, protection is provided by the facial hair, it is not very high and the presence of facial hair should not be taken as a reason to spend extended periods of time in sunlight.

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Table 1 - Hair lengths at each of the facial sites.

	Short Length (mm)	Long Length (mm)
Upper lip	10 to 14	15 to 20
Upper jaw	20 to 25	40 to 50
Mid jaw	25 to 35	70 to 80
Lower jaw	30 to 40	70 to 90
Chin	30 to 40	70 to 90

Figure 1 – The experimental set up for the dosimetric measurement of the UV protection provided by facial hair showing the rotating platform, the manikin head with the long beard, the short beard and with no beard.

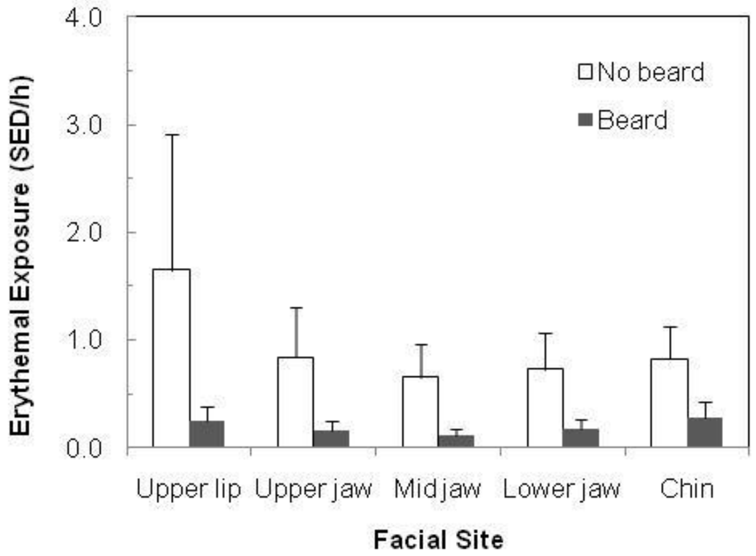

Figure 2 – Erythemal UVR exposures over a one hour period for each of the facial sites for the case of no facial hair averaged over the five SZA ranges and the case of facial hair averaged over the five SZA ranges for the results taken with the two different beard lengths. The error bars are the standard deviation of the data.

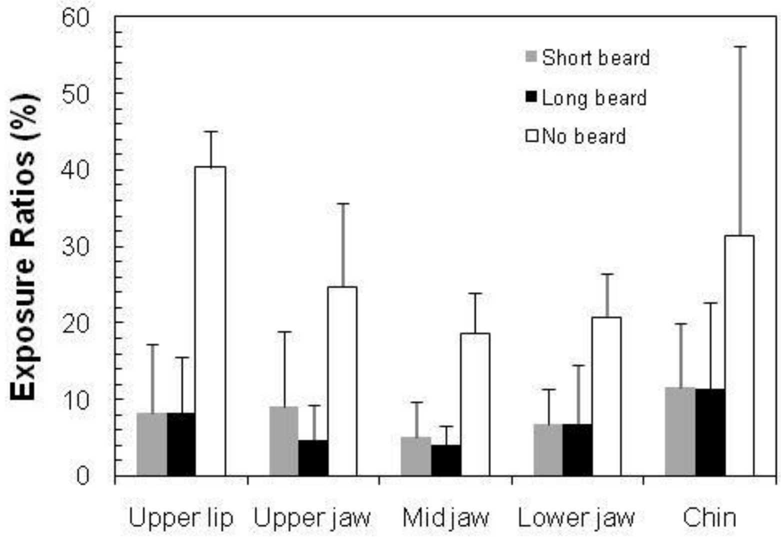

Figure 3 – The exposure ratios of the erythemal UVR exposures compared to a horizontal plane averaged over all of the SZA for each of the cases of short beard, long beard and no beard. The error bars are the standard deviation of the data.

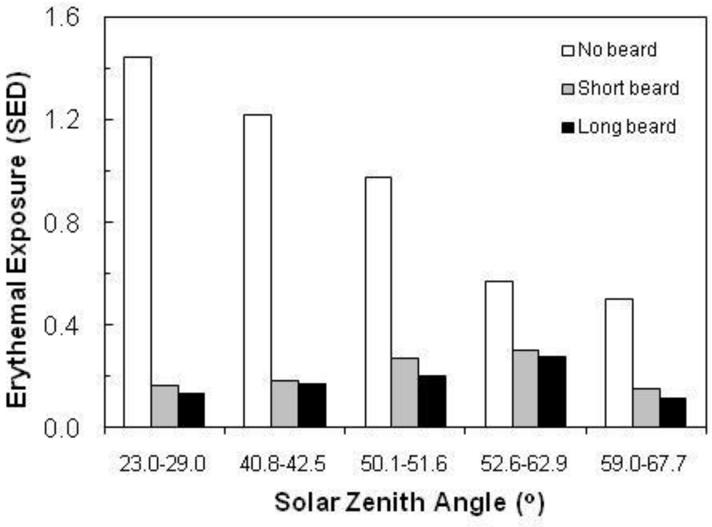

Figure 4 – The solar erythemal UVR exposures for a period of one hour averaged over each of the facial sites for the cases of no, short and long facial hair for the five SZA ranges.

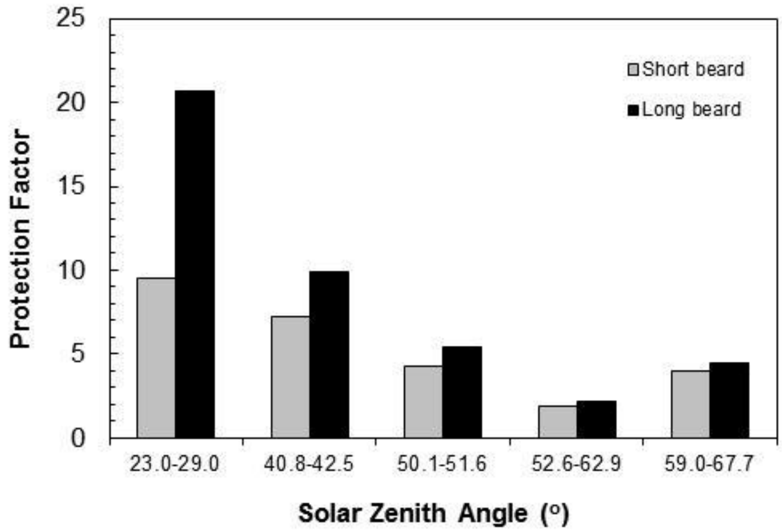

Figure 5 – The protection factors averaged over each of the facial sites for the short and long facial hair for the five SZA ranges.