Higher body anatomical distribution of Solar Ultraviolet Radiation on farm workers

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Abstract: - Many workers perform their daily activities outdoors undertaking different postures and many anatomical body sites are UVR exposed. This paper aims to compare the anatomical distribution of the solar erythemal UVR to the higher half of the body for farm workers during their usual working activity in agriculture. This research was carried out in the experimental farm"Azienda Agraria Didattico-Sperimentale" of Università Politecnica delle Marche. Measurements of solar ultraviolet radiation and ultraviolet radiation exposure received by some particular anatomical sites in the higher half of the body were investigated using a spectrometer and personal dosimeters. The measurements were carried out for seven months in 2012 for a period of time that goes from 10 a.m. to 4 p.m. characterized by the highest UVR levels. The results indicated that the UVR exposure at the nape of the neck shows higher values than the other anatomical sites.

Key-Words: - : agriculture;farm workers;UVR exposure.

1 Introduction

The incidence of sunlight-induced skin aging and skin cancers is increasing in many parts of the world. In particular, the incidence of melanoma skin cancer has shown a well-documented increase in several continents over the last few years.

The adverse effects of sunlight exposure are numerous [1 and 2]. Clinical manifestations of acute exposure include sunburn and tanning. In contrast, chronic exposure to sunlight results in wrinkling, pigment alterations, and a yellowish, coarse quality to involved skin. Chronic exposure may result in the development of cutaneous malignancies, including basal cell and squamous cell carcinomas and malignant melanoma. Many workers perform their daily activities outdoors receiving regular and significant doses of solar erythemal ultraviolet radiation(UVR).

The risk of exposure to UVR to outdoor workers was known for some time where farm workers often use little in the way of protection against solar UVR. A number of previous studies have measured the solar UVR exposure. The anatomical distribution of UVR exposure for five occupations and for a range of outdoor recreational activities was examined by Holman et al.[3]. The natural UVB radiation received by people with outdoor, indoor and mixed occupations was investigated by Larko and Diffey [4]. The UVR exposure received by office workers was analysed by Learch et al. [5]. The solar radiation exposure of outdoor workers in Queensland in the building and construction industry was measured by Gies and Wright [6]. The weekday UVR exposures to anatomical sites for outdoor workers, home workers, adolescents, indoor workers, school staff and students in South-East Queensland, Australia were evaluated by Parisi et al. [7]. The annual occupational UVR exposure of mountain guides was assessed by Moehrle et al. [8].The daily occupational erythema effective solar ultraviolet radiation exposure at selected body sites of Australia Post mail delivery personnel and physical education teachers was measured by Vishvakarman et al. [9]. The effective exposure of construction workers in a mountainous area in the southern part of Switzerland was investigated by Milon et al. [10]. The UVR exposure of Irish and Danish gardeners over a 4-month summer period during work was monitored by Thieden et al. [11]. The UVR exposure related to age, sex and occupation was studied by Thieden et al. [12].The UVR exposure of professional cyclists was investigated by Moehrle et al.[13]. The exposure to solar UVR in building workers was analysed by Antoine et al.[14]. The UVR exposure of sunbathers at a Mediterranean Sea site was monitored by Siani

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et al. [15]. The pattern of UVR exposure experience by outdoor workers from selected occupations in New Zeland was describe by Hammond et al. [16]. A monitoring of UVR exposure for farm workers during two spring months was carried out by Nardini et al. [17].

To quantify the effects of solar UVR on the human body, researchers have also studied the UVR received on inclined planes (especially the sun-normal and vertical planes) to simulate body posture ([18], [19], [20], [21], [22], [23], [24], [25], [26], [27]) as well as stationary or rotating manikins ([28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42]).

However, there seem to be a limited number of studies concerning agricultural workers, the exposure of these workers to high levels of UVR should be explored for health risks.

In this research, the measurements and the realistic variations in solar UVR at typical anatomical sites were carried out to compare the anatomical distribution of the solar erythemal UVR to the higher half of the body for standing posture of farmers. The measurements were carried out in “the field” during the usual working days and during the usual agricultural activities. Some electronic personal dosimeters (X-2000) to measure the UVR received at the cheek, nape of the neck, forehead and forearm were utilized. The UVR exposure to these anatomical sites was monitored for seven months in 2012 from 10 a.m. to 4 p.m. characterized by high UVR levels. An improved understanding of solar UVR exposure variation is helpful in deriving recommendations for how to avoid excessive exposure to some parts of the body.

2 Materials and Method

2.1 1Study location

The investigation of the UVR exposure to the higher half of the body in the year 2012 was carried out in the experimental farm “Azienda Agraria Didattico-Sperimentale”.

The Aziend aAgraria was created in 1993 to conduct research and to develop field projects on behalf of the Faculties of the Università Politecnica delleMarche.

Research activities include several crops: grapevine, olive and fruit trees (apple, pear, peach, plum, apricots, cherry), strawberry, durum wheat, sunflower, barley, corn, sorghum, beans, chick peas; breeding and variety evaluation; cultural practices such assoil fertility management, weed, insect and disease control.

The organization remains true to its broader mission in support of Marche agriculture while creating the research base for sustainable programs and initiatives to boost Marche’s economy and to conserve the regional natural products and resources.

2.1.2 Geographic and meteorological conditions

The Azienda Agraria is located in Agugliano (Latitude 43°32'40''N, Longitude13°23'25''E) at a mean altitude of 195 m above sea level in the centre of Italy near the Adriatic Sea coast. All of the measurements were acquired on sunny days with clear skies or minimal cloud cover. Whether to collect a measurement depended upon the local weather forecast.

The measurements were conducted when the mornings were sunny, but the measurement plans were aborted in the event of inclement weather during the day.

2.1.3 Study workers

Seven farm workers of the Azienda Agraria were selected to investigate higher body anatomical distribution of Solar Ultraviolet Radiation during the usual agricultural activities. The mean age of workers was 37; four were female and three were male.

Personal UVR exposure received at the cheek, forehead, forearm and nape of the neck was measured using personal dosimeters during usual working days of farmers. The farm workers were asked to follow their usual working habits. The farm workers completed a questionnaire during the exposure. The questionnaire was composed of a description of the activity within the time period of measure, body posture, time intervals and general questions on the basis of the observation of hair and eye colours, skin pigmentation and their capacity to sunburn. In addition, they were asked if they used sunscreen and other sun protections (glasses, long sleeves).

Figure 1 shows the farm workers during usual working day in an agricultural activity, lavender harvesting in some days of July.

Fig.1 farm workers during an usual working day

2.1.4 Equipment and study protocol

The incident irradiance on a horizontal surface (W m^{-2}) over a specific period was measured using a spectrometer (model CAS120, Instrument Systems).

The CAS120is equipped with a Crossed Czerny-Turner spectrograph and an array detector, and with electronic equipment for data collection and device control. The instrument is completely controlled by the software provided with it (e.g. SpecWin Pro) by USB interface. The spectral range is 200-800nm, the spectral resolution is 2.7nm, the data point interval is 0.35nm, the wavelength accuracy is +/- 0.3nm and the integration time is 4ms – 20s. The spectrometer was placed on the ground in an exposed, unobstructed area near the farm workers.

The incident erythemally weighted irradiance on some anatomical sites over a specific period, in Jm^{-2}, called UVR exposure on some specific anatomic sites, was measured using personal dosimeters (model X-2000-10, Gigahertz-Optik). The dosimeter has two cell Eyrthema lmeter with UV-A_{eff} and UV-BC_{eff} sensors. The measurement ranges for UV-A irradiance is 2mW/m² to 30W/m²and for UV-B irradiance is 0.03W/m² to 5500W/m². The CIE erythemal action spectrum [43] was considered.

Each farm worker was equipped with personal dosimeters thatwere secured to the cheek and neck using an adhesive and to the forehead and forearm using tape. The UVR exposure values were measured at 30 min intervals from 10:00 a.m. to 12:00 p.m. (lunch time from 12:00 p.m. to 2:00 p.m.) and from 2:00 to 4:00 p.m. local time for a maximum time interval of 4 hours characterized by higher UVR levels. The measurements were carried out for about 20 days for every month under test during the year 2012. The farmers sought shade in their lunch break. The upper body was exposed to a UVR regimen that often changed on second-to-second time-scale.

2.1.5 UVR exposure measurement

All UVR exposure on specific anatomical sites are described in SED units, the recommended unit for expressing personal UVR exposure, where 1 SED = 100 Jm^{-2} normalized to 298 nm according to the International Commission on Illumination erythemal action spectrum. An exposure of approximately 1.5–3.0 SED is required to produce perceptible erythema in unacclimatized white skin.

The daily UVR exposure geometric mean was calculated and analysed for each site of the body under test. To reduce the influence of season and weather conditions the percentage ambient UVR was calculated as the workers' personal UVR for a given time period divided by the concurrent available ambient UVR. Differences in exposure between the higher body anatomical distribution were examined to identify and to assess the highest UVR exposed anatomical site of farmers during the usually agriculture activities for standing posture of farmers.

3 Results and Discussion

The daily personal UVR exposure geometric mean (SED) at four different anatomical sites and the percentages of the concurrent ambient UVR are shown in Table 1 for a time interval of 14.4E+03 s for the months under test. The mean UVR exposure on specific anatomic sites presents relevant differences during the monitored months, in particular between June and July months with the highest ambient UVR levels and March, April and May. The mean daily UVR exposures on the nape of the neck were higher than 1.50 SED from May to July, while the UVR exposures on the other anatomical sites were lower than 1.50 SED during all seven months. The highest mean daily UVR exposure was 2.33 SED and it was measured on the nape of the neck in July with a corresponding percentage ambient exposure of 104.02%. The highest ambient percentage was 105.93% and it was obtained at the nape of the neck in April. The mean daily UVR exposure at the forearm, forehead, nape of the neck and cheek were different for each month, with exposure ordered across seasons as follows: winter < spring < summer. The nape of the neck exhibited the highest percentage ambient UVR and the cheek was associated with the lowest. The UVR exposure increased at the nape of the neck from the winter to summer months while it decreased at the cheek, this may be explained by the fact that this anatomical site is close to the vertical plane (slightly forward-) and the cheek may be blocked by the head during different site orientations and farm workers' movements. The UVR dose at the other anatomical sites varied in a limited range from the winter to summer months. The forearm ratios were higher than the forehead ratios. Table 1 shows the trend in exposure values at the forearm, forehead, cheek and nape of the neck sites received more than 42.37% of the mean ambient UVR. In particular, the nape of the neck received more than 93.28% of the mean UVR ambient, with a maximum of 105.93%. The calculated percentage ambient shows that the upper limit reference interval exceeds 100%, this fact is presumably due to ground reflection, posture and movements.

Table 1 Daily personal exposure geometric mean (SED) and percentage of ambient UVR (%)

	Exposure (SED)			
	forearm	forehead	cheek	nape of the neck
January	0.48	0.43	0.39	0.84
February	0.56	0.48	0.46	0.91
March	0.85	0.76	0.68	1.47
April	0.79	0.72	0.62	1.48
May	1.09	1.01	0.86	2.06
June	1.16	1.08	0.89	2.21
July	1.25	1.14	0.95	2.33
	Percentage ambient (%))			
	forearm	forehead	cheek	nape of the neck
January	56.54	50.56	45.78	99.42
February	57.68	49.18	47.61	93.28
March	56.68	50.36	45.59	97.95
April	56.26	51.60	44.01	105.93
May	55.99	51.69	44.06	105.72
June	55.13	51.38	42.37	104.96
July	55.83	51.03	42.47	104.02

Trends in exposure at four anatomical sites are similar to those on the horizontal plane and they received more than 42% of the daily UV dose. The UVR exposure at the forearm, cheek and forehead was always lower than the one on the horizontal plane, while the UVR exposure at the nape of the neck was higher than the one measured on the horizontal plane in the spring and summer months. This fact is probably due to body posture.

The UVR exposure at the nape of the neck shows higher values than the ones measured at the different anatomical sites. Therefore, the anatomical sites can be placed in descending order of UVR exposure as follows: nape of the neck>forearm>forehead>cheek. This fact can be justified by particular anatomical site orientation and body movements.

Figure 2 shows the diurnal variations in daily UVR exposure at the forearm, forehead, cheek and nape of the neck during the months under test.

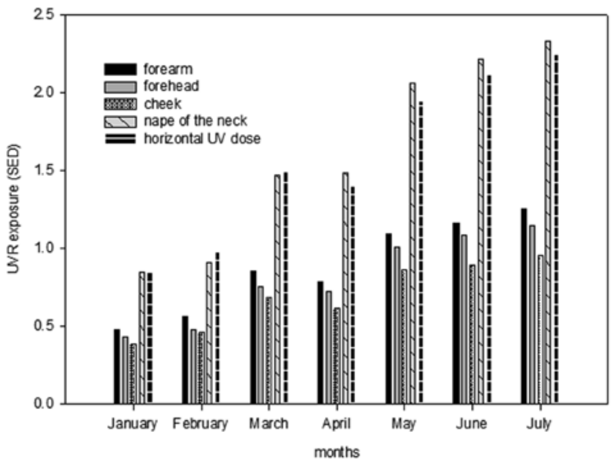

Figure 2. Daily UVR exposure geometric mean in the monitored months under test at four anatomical sites and on the horizontal plane

Figure 3 shows the daily UVR exposure geometric mean per hour at nape of the neck for each month. In each month the diurnal variations in solar UVR exposure at the nape of the neck shows two peaks, one in the morning at about 11:15 a.m. and the other one in the afternoon at about 2:00-3:00 p.m., while the minimum values were measured at about 10:00 a.m. and 4:00 p.m. except for June (3:00 p.m.).

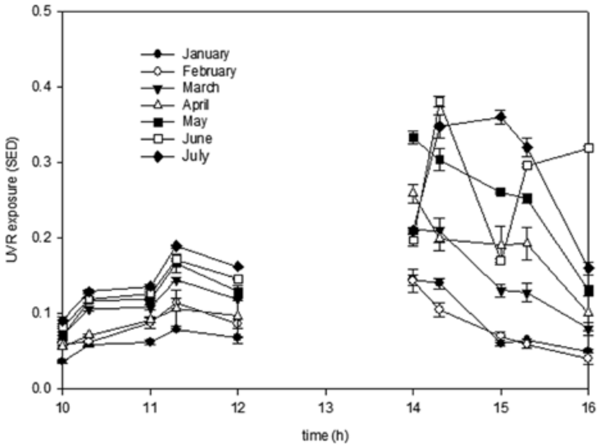

Figure 3 UVR exposure geometric mean per hour at the nape of the neck

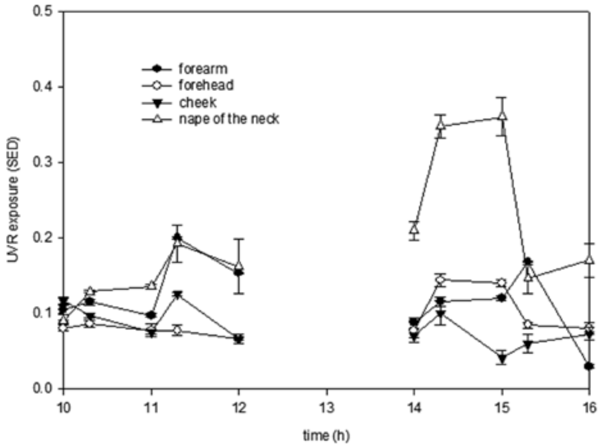

Figure 5 UVR exposure geometric mean per hour at four anatomical sites in July

Figure 4 shows the UVR exposure geometric mean per hour at the forearm, forehead, cheek and nape of the neck in May and Figure 5 in July. In each month, the diurnal variations in solar UVR exposure at each anatomical site shows two peaks, one in the morning at about 10:30-11:30 a.m. and the other one in the afternoon at about 2:00-3:00 p.m..While the minimum values were measured at 4:00 p.m. for the forearm, forehead, cheek and nape of the neck, at 10:00 a.m. for the forearm and nape of the neck and at 12.00 p.m. for the forehead and cheek.

This fact is due to particular anatomical site orientation and body movements. In the morning at about 11:00 a.m. the UVR exposure is highest at the forearm. This may be explained by the fact that this anatomical site is close to the vertical plane (slightly forward) and the forearm may be blocked by the head during different site orientations and farmer movements.

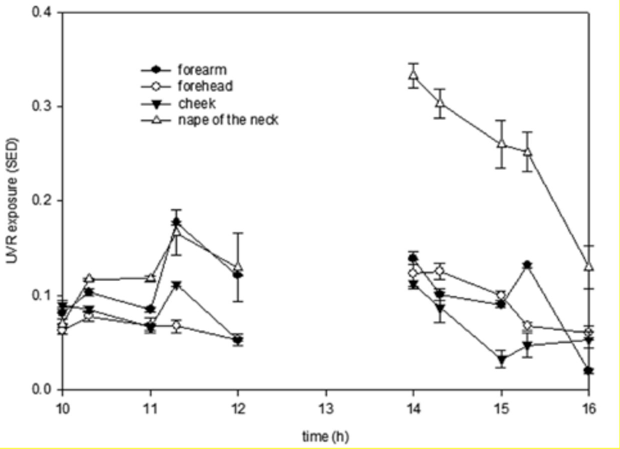

Figure 4 Daily UVR exposure geometric mean per hour at four anatomical sites in May

4 Conclusion

The UVR exposure at the higher half of the body (the forearm, forehead, cheek and nape of the neck) was investigated for standing posture for farmers in the Azienda Agraria to assess the UVR hazard and to identify the anatomical site more exposed to UVR. Measurements were carried outduring the usual working days and usual agricultural activitiesfor seven months from 10 a.m. to 4 p.m. characterized by highest UVR levels. The percentage ambient UVR was measured with UVR dosimeters for standing posture of seven farm workers; its values ranged from 45-98% for the different anatomical sites in winter (January, February and March), from 44-106% in spring (April and May) while in the summer (June and July)they ranged from 42% to 105%. The exposure to each site was dependent on the particular anatomical site orientation. The results for the higher half of the body for standing posture of farmers show that the UVR exposure at the nape of the neck is relevant and it has higher values than the different anatomical sites. In fact the anatomical site most exposed was the nape of the neck, then in ascending order theforearm, forehead and cheek. An exposure of approximately 1.5–3.0 SED is required to produce perceptible erythema in unacclimatized white skin. The daily UVR exposure geometric means on the nape of the neck were higher than 1.50 SED from May to July with a maximum value of 2.33 SED measured with correspond percentage ambient exposure of 104.02%. The variation of the daily UVR exposure per hour at the nape of the neck showed a maximum value in the morning at 11:00-11:15 a. m. and in the afternoon at 2:00 p.m.. This fact can be justified by particular anatomical site orientation by body movements and solar elevation angle.

The results provide a first order of magnitude evaluation of the differences of the UVR exposure in the anatomical distribution in the standing posture. However, comparing the results of the present study with those of other personal UVR dosimetry studies is problematic because of differences in study design, such as the anatomical attachment site of the personal UVR monitor. UVR exposure is known to vary significantly between sites, measurement duration, latitude, solar zenith angle, season, weather conditions, altitude, atmospheric composition and ground albedo. Furthermore, the amount of UVR actually received depends on the protective practices adopted.

Real-time exposure data suggests that it may be useful to remind workers of the risks associated with spending increased time in the sun exposure. Ideally, workers should be rescheduling work tasks that involve substantial sun exposure by delaying them until late afternoon, or more likely early in the morning. Using the lunch break to increase personal protection should be emphasized. As well as advising workers to seek shade during their lunch break; they should be advised to work in shaded areas where possible.

The results of this study can potentially be helpful in preventing the UVR diseases. The risk of non-melanoma skin cancer and malignant melanoma will increase if no protective measures against over exposure to solar UVR radiation, such as clothing or sunscreen are employed. The results of this study can potentially be helpful in preventing the UVR-induced skin diseases. Thus, they may encourage individuals to plan their outdoor activities to prevent excessive UVR exposure, especially to the nape of the neck. Nevertheless, further research is required to collect data on the exposure ratios for each month of the year and different atmospheric conditions and surface albedo. Additionally, humans stand in a variety of different postures and the exposure ratios may vary for different standing postures.

Acknowledgements

This study was supported by Direzione Regionale INAIL Marche. The authors acknowledge dr. G. Murri and L. Borghesi and the workers of the experimental farm of Università Politecnica of Marche.

References:

[1] B.L. Diffey, Climate change, ozone depletion and the impact on ultraviolet exposure of human skin, *Phys. Med. Biol*, Vol.49, R1–R11, 2004

[2] D.E. Godar, UV doses worldwide,. *Photochem Photobiol*, Vol.81,2005, pp. 736–749

[3] C.D. Holman, I.M. Gibson, M. Stephenson, B.K. Armstrong, Ultraviolet irradiation of human body sites in relation to occupation and outdoor activity: field studies using personal UVR dosimeters, *Clin Exp Dermatol*, Vol. 8(3), 1983, pp.269-277

[4] O. Larko, B.L. Diffey, Natural UV-B radiation received by people with outdoor, indoor, and mixed occupations and UV-B treatment of psoriasis, *Clin Exp Dermatol*, Vol.8, 1983, pp. 279–285

[5] J.F. Leach, V.E. McLeod, A.R. Pingstone, A. Davis, G.H.W. Deane, Measurement of the ultraviolet doses received by office workers,. *Clin Exp Dermatol*, Vol. 3, 1977, pp.77–79

[6] P. Gies, J. Wright, Measured Solar Ultraviolet Radiation Exposure of Outdoor Workers in Queensland in the Building and Construction Industry, *Photochemistry and Photobiology*, Vol.78(4), 2003, pp.342-348

[7] A.V. Parisi, L.R. Meldrum, M.G. Kimlin, J.C.F Wong, J. Aitken, J.S. Mainstone, Evaluation of differences in ultraviolet exposure during weekend and weekday activities, *Phys Med Biol*, Vol.45, 2000, pp.2253–2262

[8] M. Moehrle, B. Dennenmoser, C. Garbe, , Continuous long-term monitoring of UV radiation in professional mountain guides reveals extremely high exposure, *Int J Cance*r, Vol.103, 2003, pp. 775–8

[9] D. Vishvakarman, J.C. Wong, B.W. Boreham, Annual occupational exposure to ultraviolet radiation in central Queensland, *Health Phys*, Vol.81, 2001, pp. 536–44

[10] A. Milon, S. Pierre-Edouard, J.L. Bulliard, D.Vernez, Effective exposure to solar UV in building workers: influence of local and individual factors, *J Expos Sci Environ Epidemiol*, Vol.17, 2007, pp. 58–68

[11] E. Thieden, S.M. Collins, P.A. Philpsen, G.M. Murphy, H.C. Wulf, Ultraviolet exposure patterns of Irish and Danish gardeners during work and leisure,. *Br J Dermatol*, Vol.153, 2005, pp.795–801

[12] E. Thieden, UV radiation exposure related to age, sex, occupation, and sun behaviour based on time-stamped personal dosimeter readings,.

Arch Dermatol, Vol.140(2), 2004, pp. 197-203,. doi:10.1001/archderm.140.2.197

[13] M. Moehrle, L. Heinrich, A. Schmid, Garbe, Extreme UV exposure of professional cyclists,. *Dermatology*, Vol.201, 2000, pp.44-45

[14] M. Antoine, S. Pierre-Edouard, B. Jean-Luc, B., V. David, Effective exposure to solar UV in building workers: influence of local and individual factors, *J Expo Sci Environ Epidemiol*, Vol. 17(1), 2007, pp. 58-68

[15] A.M. Siani, G.R. Casale, R. Sisto, M. Borra, M.G. Kimlin, C.A. Carolyn, A. Colosimo, Short-term UV exposure of sunbathers at a Mediterranean Sea Site, *Photochemistry and Photobiology*, Vol 85, 2009, pp171-177

[16] V. Hammond, A.I. Reeder, A. Gray, Patterns of real-time occupational ultraviolet radiation exposure among a sample of outdoor workers in New Zeland, *Public Health*, Vol.123, 2009, pp.182-187

[17] G. Nardini, M. Paroncini, D. Candido, M. Della Pasqua, Analysis of UV exposure for farmers: first experimental results, CIGR-Ageng12, International Conference of Agriculture Engineering, 08-12 July 2012, Valencia, Spain, ISBN – 10: 84-615-9928-4

[18] A.R. Webb, P. Weihs, M. Blumthaler, Spectral UV irradiance on vertical surfaces: a case study, *Photochem Photobiol*, Vol. 69(4), 1999, pp. 464-470

[19] A.V. Parisi, M.G. Kimlin, Horizontal and sun-normal spectral biologically effective ultraviolet irradiances, *J Photochem Photobiol*, Vol. B 53(1-3), 1999, pp. 70-74

[20] P.Weihs, Influence of ground reflectivity and topography on erythemal UV radiation on inclined planes. *Int J Biometeorol*, Vol. 46(2),, 2002, 95-104

[21] A. Oppenrieder, P. Hoeppe, P. Koepke, Routine measurement of erythemally effective UV irradiance on inclined surfaces, *J Photochem Photobiol*, Vol. B 74(2-3), 2004, pp. 85-94

[22] R. Philipona, A. Schilling, D. Schmucki, Albedo-enhanced maximum UV irradiance-measured on surfaces oriented normal to the sun. *Photochem Photobiol* 73(4), 2001, pp. 366-369

[23] J. Turner, A.V. Parisi, D.J. Turnbull, Reflected solar radiation from horizontal, vertical and inclined surfaces: Ultraviolet and visible spectral and broadband behaviour due to solar zenith angle, orientation and surface type, *J Photochem Photobiol*, Vol. B92(1), 2008, pp. 29-37

[24] G. Schauberger, Model for the global irradiance of the solar biologically-effective ultraviolet-radiation on inclined surfaces. Photochem Photobiol, Vol.52(5), 1990, pp. 1029-1032

[25] A. Oppenrieder, P. Hoeppe, P. Koepke, Routine measurement of erythemally effective UV irradiance on inclined surfaces. J *PhotochemPhotobiol*, Vol.B 74(2-3),2004, pp. 85-94

[26] R.L. McKenzie, K.J. Paulin, M. Kotkamp, Erythemal UV irradiances at Lauder, New Zealand: relationship between horizontal and normal incidence, *Photochem Photobiol*, Vol. 66(5), 1997, pp.683-689

[27] P. Hoeppe, A. Oppenrieder, C. Erianto, P. Koepke, J. Reuder, M. Seefeldner, D. Nowak, Visualization of UV exposure of the human body based on data from a scanning UV-measuring system, *Int J Biometeorol*, Vol.49(1),2004, pp. 18-25

[28] M. Ono, Studies on ultraviolet radiation and health effects: ocular exposure to ultraviolet radiation. *Dev Ophthalmol*, Vol.35,2002, pp. 32-39

[29] D.K. Airey, J.C. Wong, R.A. Fleming, A comparison of human- and headform-based measurements of solar ultraviolet B dose. *Photodermatol Photoimmunol Photomed*, Vol. 11(4), 1995, pp. 155-158

[30] M.G. Kimlin, A.V. Parisi, J.C. Wong, The facial distribution of erythemal ultraviolet exposure in south-east Queensland, *Phys Med Biol*, Vol.43(2), 1998, pp.231-240

[31] Y. Sakamoto, M. Kojima, Y. Emori, Y, Ultraviol dosimetry utilizing a mannequin model, *Dev Ophthalmol*, Vol. 27, 1997, pp. 50-55

[32] A.V. Parisi, M.G. Kimlin, R. Lester, D. Turnbull, Lower body anatomical distribution of solar ultraviolet radiation on thehuman form in standing and sitting postures, *J Photochem Photobiol B*, Vol: Biology 69, 2003, pp. 1–6

[33] P. Gies, J. Javorniczky, C. Roy, Measurements of the UVR protection provided by hats used at school. *Photochem Photobiol*, Vol.82(3),2006, pp. 750-754

[34] C.F. Wong, R.A. Fleming, S.J. Carter, Measurement of human exposure to ultraviolet-B solar radiation using a CR-39 dosimeter, *Health Phys*, Vol.63(4),1992, pp. 457-461

[35] B.L. Diffey, J. Cheeseman, Sun protection with hats, *Br J Dermatol*, Vol.127(1), 1992, pp. 10-12
[36] A.V. Parisi, M.G. Kimlin, J.C. Wong, Personal exposure distribution of solar erythemal ultraviolet radiation in tree shade over summer, *Phys Med Biol*, Vol. 45(2), 2000, pp. 349-356
[37] M.M. Sydenham, M.J. Collins, L.W. Hirst, Measurement of ultraviolet radiation at the surface of the eye, *Invest Ophthalmol* Vis Sci Vol. 38,1997, pp. 1485-1492
[38] J.C. Merriam, The concentration of light in the human lens, *Trans Am Ophthalmol*, Vol. Soc94, , 1996, pp. 803-918
[39] B. Birt, I. Cowling, S., Coyne, The effect of the eye's surface topography on the total irradiance of ultraviolet radiation on the inner canthus, *J PhotochemPhotobiol*, Vol. B87(1),2007, pp. 27-36
[40] C.D. Holman, I.M. Gibson, M. Stephenson, Ultraviolet irradiation of human body sites in relation to occupation and outdoor activity: field studies using personal UVR dosimeters, *Clin Exp Dermatol*, Vol. 8(3),1983, pp. 269-277
[41] B.L. Diffey, M. Kerwin, A. Davis, The anatomical distribution of sunlight, *Br J Dermatol*, Vol.97,1997, pp. 407-410
[42] L.W. Hu, Q. Gao, W.Y. Xu, Y. Wang, H.Z. Gong, G.Q. Dong, J.H. Li, Y. Liu, Diurnal Variations in Solar Ultraviolet Radiation at Typical Anatomical Sites, *Biomedical and Environmental Science*, Vol. 23, 2010, pp. 234-243
[43] C.I.E(Commission Internationale d'Eclairage) Research Note. A reference action spectrum for ultraviolet induced erythema in human skin, *CIE J*, Vol. 6,1987, pp. 17–22.