Ultraviolet Exposure for Different Outdoor Sports in Valencia, Spain.

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Summary

Background: The purpose of this study is to quantify UV exposure of several groups of amateur athletes in their training or recreational schedules.

Methods: The athletes were monitored using dosimeters (VioSpor).The study took place in Valencia, Spain, from May to July 2010, and involved a group of 10 mountaineers, four tennis players, and five runners.

Results: The mean daily personal UV exposure for mountaineers was 9.48±3.23 Standard Erythema Dose (SED). The tennis players received a mean of 10.65±1.57 SED for every two days of training, and the runners received a mean of 7.62±4.28 SED for every five days of training.

Conclusion: Mountaineers received a higher dose of UV exposure and have a higher Exposure Ratio than the tennis players, probably because they spent more time outdoors. However, the runners received a low dose of UV exposure, perhaps because their training takes place in the evening. Mean daily UV exposure of the mountaineers and tennis players exceeded 5 SED, which means that, in the case of non sun-adapted skin type III and the non-use of sun protection, erythema may be induced in these subjects. Accordingly, it is necessary to encourage the use of high protection sunscreens and protective clothing, and to avoid UV exposure in the hottest part of the day.

Keywords: ultraviolet erythemal radiation; UVER exposure; exposure ratio; personal dosimetry; Viospor.

Introduction

It is well known that exposure to UV radiation is one of the most important risk factors in the development of melanoma and other skin cancers (1, 2, 3, 4). Exposure mainly occurs during outdoor occupational or recreational activities.

Solar exposure also has a beneficial effect on human health, such as the synthesis of vitamin D (5). Moreover, appropriate vitamin D levels have been suggested as being beneficial against breast, prostate, and colon cancers (6).

People taking part in outdoor sports receive regular and significant solar ultraviolet erythemal radiation (UVER) in their training and recreational schedules during the summer months and probably are at higher risk of developing skin cancer. Mountaineering, tennis, and running are among the most popular outdoor activities. The aim of this article is to study the UVER exposure of these groups during their training or recreational activities.

Although the practice of sport in general is widely recommended by the medical profession for its beneficial effects on the cardiovascular system, it is also true that sportsmen/women are potentially exposed to harmful doses of UV radiation, especially during long training sessions. Several studies showing the appearance of skin melanomas in marathon runners (7) and cyclists (8) support the idea that these activities may increase the risk of cancer.

Among the outdoor recreational activities considered in this study, the activity with the highest measured UV exposure and the largest number of studies is mountaineering (9, 10, 11, 12). In contrast, there are few studies on the UV exposure of runners (7, 13) and tennis players (14) while taking part in these sports. Another of the most widespread outdoor sports is cycling and some papers have shown that this is an activity with a high UV exposure (15, 16).

Materials and methods

Study location

The study took place in the Spanish region of Valencia from May to July 2010. It involved a group of 10 mountaineers over a period of three mountain hikes, a group of four tennis players for a period of six training days, and five runners over 15 training sessions. The mountaineers undertook three hikes during the month of May (on 8^{th}, 15^{th} and 22^{nd}) in several locations 60 to 120 km from Valencia. The hikes were 15.5 to 23 km long (about 6.5 hours) and the maximum altitude was 1839 metres.

The study on tennis player exposure took place at a tennis club in Valencia (coordinates 0º 22 ' W, 39º 28 ' N, sea level) during the month of June (on 12^{th}, 13^{th}, 19^{th}, 20^{th}, 26^{th} and 27^{th}).

The study on runner exposure took place on the campus and surrounding areas of the Universidad Politécnica de Valencia (UPV) during the months of June and July.

Subjects and design

Participants taking part in the study included: ten subjects, four women and six men, from the UPV mountain climbing group; four men (one coach and three students) from a tennis club; and five randomly selected subjects (men) from the UPV athletics club. The subjects completed a questionnaire where they stated the time at which they put on and removed the dosimeter and the number of hours spent outdoors. As the purpose of this paper was to study the maximum solar exposure received during their activities, subjects were told to use dosimeters if most of the sky were cloudless at the beginning of their training or recreational day. Subjects were also asked not to change their behaviour during the measurements and to continue with their normal schedules.

Personal UVER dosimeters

To measure the exposure of these groups of athletes, a UV sensitive spore-film filter system (VioSpor Blue Line Type I Dosimeter, Bio-Sense, Bornheim, Germany) (17) was used. It has been proven that these dosimeters can be used effectively for personal UV measurements in outdoor occupations such as lifesaving (9, 18), or mountain guides (9, 10), and in recreational activities such as cycling (13, 15, 16), or running (13).

Spore-film production (DNA repair-deficient strain of *Bacillus subtilis*) and the development of the films were described in Furusawa *et al.* (19) and Munakata *et al.* (20). The spore films are covered by a filter system with optical properties simulating the erythemal response of human skin in accordance with the International Commission on Illumination (CIE) reference spectrum (21) and mounted in waterproof casings with a diameter of 32 mm. The working range used is 0.5-22.5 SED J/m^2 and the measurement error is ±10%, according to the manufacturer. The measurements are expressed as a standard erythema dose (SED) of biologically effective ambient solar UV radiation, where 1 SED is defined as effective exposure of 100 J/m^2 (22) when weighted with the CIE erythemal response function (21).

The VioSpor system is subject to constant quality control. System validation is carried out using in-vivo comparative measurements (23). The wavelength-specific calibration of VioSpor is carried out using measurements on the Okasaki spectrograph in Japan (lamp performance based on the US radiation strength norm of the National Institute of Standards) (19, 20).

Additionally, VioSpor was validated during several instrument intercomparisons performed under field conditions. VioSpor data were compared with the minimal erythema dose values calculated from spectroradiometer data (24).

The individual cumulative solar UVER exposure was measured by a VioSpor dosimeter Type I. Mountaineers used a dosimeter for each day, tennis players changed theirs every two training days and runners every five training days. Half of the mountaineers wore the UVER dosimeters placed on the top of their cap and the other half on their wrist, throughout their recreational day, approximately from 11:00 am to 5:30 pm. The cap was chosen as it receives the highest UVER exposure on the body, as shown in Kimlin *et al*. (25). Tennis players, from 10:00 am to 1:30 pm, and runners, starting at 7:00 pm, used the dosimeters attached to Velcro straps on the wrist, as this is considered the most practical and suitable anatomical site for measuring solar UV exposure (26).

Ambient UVER exposure

Ambient UVER was recorded with a UVB-1 radiometer (Yankee Environment System, YES), belonging to the Valencia regional government's (GV) UVB measurement network (27), located at 00º20'09" W 39º27'49" N, on a flat roof without obstructions or shade on a building in the city of Valencia.

The sensor is a broadband radiometer, model UVB-1 YES, which measures in the range 280-400 nm by providing a single integrated value for the whole measurement range. The instrument response is similar to the erythemal action spectrum, and so this sensor is capable of measuring the effective erythemal ultraviolet radiation (UVER).

The measuring station also includes a stabilised uninterruptible power supply, a mast assembly platform for the radiometer, a communication antenna, and a closet for elements with pre-installation of electrical and mechanical components. The UVB-1 pyranometer is designed to be stable for long periods and for field work without supervision.

The calibration uncertainty is approximately 10%. The cosine response is less than 4% for solar zenith angles below 55º (according to the manufacturer). This calibration consisted of a measurement of the spectral response of the radiometer indoors and a comparison with a Brewer MKIII spectroradiometer outdoors (28, 29).

It should be noted that the YES UVB-1 presents non-negligible errors for high zenith angles unless a double entry zenith angle–ozone calibration matrix is used (28). For a constant ozone value of 300 Dobson Units (DU), the error given by the calibration matrix remained below 9% for zenith angles below 70°. Additional calibration of this radiometer was carried out by the Earth Physics Department of the Universitat de València by comparison with an Optronic OL-754 spectroradiometer equipped with a double monochromator with a spectral range that extends from 250 nm to 800 nm. The values given by the latter equipment were convolved with the erythemal action spectrum and then integrated and compared with the values obtained with the UVB-1 (30, 31).

UV exposure limits

The International Radiation Protection Association established exposure limits (EL) in its recreational/occupational UV exposure standard in 1985 (32). These were later adopted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and updated in 2010 (33). The ICNIRP recommends a maximum personal daily exposure of 30 J/m^2 effective UV dose within an 8-hour period for sensitive unprotected skin using the

American Conference of Governmental Industrial Hygienists (ACGIH) action spectrum (34). This limit is equivalent to 1.09 SED (16) using the CIE action spectrum (21).

An obvious effect of skin adaptation from frequent UV exposure is skin darkening, but the skin also thickens. This thickening after sun exposure leads to a significant increase in UV protection by a factor of five or greater (33).

A value of 12 SED for Mediterranean subjects with skin phototype III is assumed to be the self-protection factor of sun-adapted skin, and a value of 5 SED is adopted for the same type of skin but without adaptation to the sun (33). Exposure above 12 SED denotes high risk.

The measured exposure of athletes was compared with the value of 5 SED, since we have considered subjects with non sun-adapted skin type III, and with the EL value.

Statistical analysis

Data was analysed using the Statistical Package Statgraphics Plus software v5.1 and are expressed as mean±standard deviation (SD). The coefficient of variation (CV), a normalised measurement of dispersion of a probability distribution, was also calculated to establish if the subjects within each study behave as a homogeneous group. The CV is defined as the ratio of the SD to the mean. Differences in the mean UV doses according to gender and dosimeter position were compared assuming a t-distribution. The F-test in the ANOVA tool was used to compare differences between subjects (runners) in terms of ER or SED/hour outdoors. Statistical significance was set at $p \leq 0.05$ for all analyses.

Results

Ambient solar UVER

Measurements of daily ambient UVER recorded by the radiometer belonging to the GV station and the corresponding maximum UV index (UVI) (35, 36) for the periods of the study is shown in Table 1. Table 1 also lists the temperature data provided by the national meteorology agency (37) and ozone data from the NASA ozone monitoring instrument (OMI) (38). As can be seen from the table, the solar UVI is quite high, 8 or 9, but normal for the time of year in Valencia. The total column ozone amount from the OMI measurements for Valencia varied from 314 DU on 1st July to 378 DU on 13th June.

Measured UVER exposures

Mountaineering group. The mean daily UV exposure was 9.48±3.23 SED, and per hour outdoors was 1.43±0.48 SED as shown in Table 2. The exposure ratio (ER) was defined as the ratio between the personal dose on a selected anatomical site and the corresponding ambient dose on a horizontal plane during the same day of exposure. Table 2 lists the mean averages of the exposures recorded for the corresponding day as a percentage of the measured daily total ambient UVER. Mean ER was, as a percentage, 21.7±7.4. If we calculate the ratio of the personal dose to ambient UVER for the time of exposure, a mean value of 25.7±8.5 was obtained as a percentage.

The CV was calculated to see whether the mountaineers behaved as a homogeneous group with respect to outdoor UVER exposure. Since the CVs obtained for the mountaineers are about 35%, we conclude that some subjects received consistently higher or lower exposures than their peers.

The SD of UVER exposure for each day shown in Table 2 and this gives a measure of the variability between subjects. The value of SD is similar for the three days, indicating that the individuals behaved similarly every day.

The results discussed above are sub-classified by gender and by dosimeter position in Table 2. No significant difference was found, in terms of the SED received, regarding gender ($p=0.9$) or dosimeter position ($p=0.17$).

Tennis player group. The mean two-day UV exposure of this group was 10.65±1.57 SED, and the hourly outdoor reading was 1.52±0.22 SED, as shown in Table 3. Table 3 also lists the mean averages of the exposures recorded for the corresponding day as a percentage of the daily total ambient UVER measured. Mean ER, as a percentage, was 11.9±1.5. The ratio of the personal dose to ambient UVER for the time of exposure yields a mean value, as a percentage, of 30.6±4.5.

The CV was taken into account to establish whether the tennis players behaved as a homogeneous group with respect to outdoor UVER exposure. Since the mean CV obtained is below 15%, we conclude that the individuals behaved similarly. The SD of UVER exposure for each day shown in Table 3 gives a measure of the variability between subjects. The value of SD is similar for the three days, indicating that the individuals behaved similarly during their daily activities.

Runner group. The mean five-day UV exposure of this group was 7.62±4.28 SED, and the hourly outdoor reading was 0.59±0.61 SED as shown in Table 4. Table 4 also lists the mean of the exposures recorded for each subject as a percentage of the daily total ambient UVER measured. The mean ER for all runners was, as a percentage, 1.90±1.79.

The CV was calculated in order to see whether the runners behaved as a homogeneous group with respect to outdoor UVER exposure. Since the mean CV obtained is about 95%, we conclude that some subjects received consistently higher or lower exposures than their peers.

The SD of UVER exposure for each subject shown in Table 4 gives a measure of the variability between the measurement days for each runner, and reveals whether behaviour is more or less consistent. In order to see whether there was a significant difference between the SD of UVER exposure received for each runner, the contrast of variances in the Statgraphics program was applied to the sample of such SDs. As the smallest of the p-values was less than 0.05, there is a statistically significant difference between the standard deviations with a confidence level of 95.0%. Runners 1 and 3 had a high value for the SD, indicating that their behaviour is not consistent, while the other runners behaved more consistently during the measured days.

In order to see whether there was a significant difference between the UVER doses received by each runner, and since the training time was different for each of them, the F-test of the ANOVA tool was applied to the sample of SED per hour for each runner. This test was also applied to the sample of the ER of each runner. The results of the p-value indicate that there were no statistically significant differences between subjects with regards ER (p=0.50) or SED per hour of training (p=0.65).

Discussion

Moehrle *et al.* (9) found a mean daily personal exposure of 29.8 SED for 23 different mountaineering activities at different locations during the spring and summer. In another study, Moehrle *et al.* (10) measured the personal UV exposure of nine mountain guide instructors during one year, and obtained a mean UV dose per day of 6.6 SED. In both papers, Moehrle *et al.* used a vertically oriented dosimeter attached laterally to the head – whereas we used two different positions. We found a mean daily exposure, in spring, of 9.48 SED, similar to that of Moehrle taking into account these differences.

Herlihy *et al.* (14) studied the UV exposure in summer for six outdoor activities, including tennis, at seven anatomical sites. A mean daily UV exposure of 8.7 SED was obtained for tennis, and an ambient fraction of 0.43 for a hand dosimeter position. We found a mean daily exposure, in summer, of 5.3 SED, and an ER of 0.31 on the wrist, comparable to the previous figure because we also calculated the ratio of exposure to the exercise time.

Finally, Moehrle (13) studied personal UV exposure on the back (between the shoulders) of several triathletes during the Ironman Triathlon World championships 1999 in Hawaii and found that triathletes received a mean of 20.8 SED. We obtained a mean daily exposure, in summer, of 0.86 SED; very different to that of Moehrle. These values are not comparable because our runners train in the evening – while the triathlon takes place in the middle of the day with higher solar radiation.

An outdoor occupational activity with a high UV exposure is lifesaving. In Valencia, Serrano *et al.* (18) measured the UV exposure of a group of five lifeguards for a period of several days in the summer and found that they received a two-day UV exposure of 22.9 SED.

Mountaineers and runners did not behave as a homogeneous group with respect to outdoor UVER exposure, so we conclude that some subjects received consistently higher or lower exposures than their peers. The observed variations of doses, ER and UVER, although non-significant, might be due to inter-individual variations of exposure angles of the dosimeters with respect to the sun. Moreover, the mountaineers and runners did not train all the time in the same group. Therefore, fixation of the head and wrist position of the dosimeter varied and dosimeters were not fixed at the same place or altitude with the same exposure of the dosimeter to the sun – and this may explain the variations. However, in spite of these variables, ER showed good consistency.

In contrast, the tennis players did behave as a homogeneous group with respect to outdoor UVER exposure – as expected, as the players train in a bounded area - indicating that the individuals presented the same behaviour with respect to their daily activities.

Mean daily UV exposure of the mountaineers and tennis players (9.48 SED and 5.3 SED respectively) exceeded 5 SED, which means that in the case of non sun-adapted skin type III and non-use of sun protection, erythema can be induced in these individuals.

In addition, UV exposure exceeded the ELs, so that the subjects engaged in these recreational/occupational activities received up to 5-9.5 times the recommended UVER exposure for outdoor activities, indicating that protective measures such as high quality protection equipment and the use of sunscreens are absolutely necessary.

Although the measurements of the mountaineers were made in May and the measurements of the tennis players in June, the two can be compared since the daily ambient UVER is similar, about 4400 J/m^2 and also the UVI, about 8-9 (Table 1), for the two periods of the study. Mountaineers with wrist dosimeters received a higher dose of UV exposure and have a higher ER than the tennis players, probably because they spent more time outdoors (6.6 h against 3.5 h per day), since if we compare the SED received relative to the time spent outdoors then both groups received an equivalent dose per hour outdoors (1.30 versus 1.52, both measured at the wrist). It is also known that there is an increase in solar UV radiation with altitude (39), but since the tennis players receive higher doses per hour, the reason for the higher dose received by mountaineers lies in their longer exposure to the sun. This is so because, after calculating the ratio of exposure to the time of exercise, the players have a higher percentage than the mountaineers, 30% vs 25%, indicating that, during the exercise period, the tennis players received a higher percentage of ambient UVER than mountaineers.

Moreover, the ER of the mountaineers is calculated for the ambient UVER of Valencia, which is lower than the ambient UVER of the hike location, at a rate that can range between 5% for the hike at a lower mean altitude (330 m) and 25% for the hike at the highest mean altitude (1439 m). These percentages were calculated taking into account the increase in UVER with altitude cited in the article by Blumthaler *et al*. (39). As a result of this, the ER calculated for the mountaineers are higher than those received by them, as the ambient UVER in Valencia is lower than the ambient UVER at the hike location.

Furthermore, another reason that the tennis players receive higher doses per hour is that the tennis courts are not normally covered, nor are there trees to provide shade, while the mountaineers undertake their sport in the mountains, where there are many trees that provide shade.

The runners received a mean daily UV exposure of 0.86 SED and did not reach the maximum personal exposure of 5 SED. The low value of the UV exposure dose may be due to the training schedule of the study group, as they begin to train at 7 pm.

Since these sportsmen and women can spend up to seven hours per day exposed to UV radiation during their summer recreational/training activities, it is difficult for groups who exercise in the hottest part of the day (mountaineers and tennis players) to avoid UV exposure. Therefore, the use of sunscreens and protective clothing are essential strategies. It is known that the dual needs of protective clothing and of transpiration and body cooling in outdoor sports are difficult to balance. Accordingly, it is necessary to encourage the use of high protection sunscreens.

Finally, a personal VioSpor film dosimeter was used to measure the recreational UV exposure of some groups of amateur sportsmen and women, and we conclude that two of these groups exceeded the international UV threshold level for non sun-adapted Mediterranean skin.

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Table 1 Actual mean temperature (with maximum and minimum in brackets), data of ozone concentration from ozone monitoring instrument (NASA), ambient UVER and UV index from the UVER (W/m^2) YES UVB-1 radiometer at Valencia Generalitat station

Date	Air temperature (ºC)	Ozone (Dobson Units)	Ambient UVER (J/m^2)	UVI
08/05/2010	17.7 (24.4-13.1)	-	4243,9	9
15/05/2010	17.6 (23.0-12.6)	-	4187,16	8
22/05/2010	18.7 (23.0-13.9)	349	4631,88	8
12,13/06/2010	20.8 (25.7-18.0)	375,378	7965.54	9,8
19,20/06/2010	21.6 (27.1-17.9)	356,-	9592.6	8,9
26,27/06/2010	22.7 (22.8-18.3)	351,-	9060.72	8,8
1,7,8,10,17/06/2010	21.8 (27.4-15.5)	314,357,353,392,358	23425,24	9,8,8,8,9
24,28/6 5,6,8/07/2010	23.9 (29.0-17.9)	336,-,328,-,-	23434,68	9,8,9,9,8
13,15,22,26,27/07/2010	25.4 (29.0-19.9)	-,320,-,316,323	24029,03	8,9,9,9,9

Table 2 UVER exposure (given in SED) measured using Viospor dosimeters, and exposure ratio for the mountain group

	UVER exposure					
	Mean (SED)	Standard deviation (SED)	Coefficient of variation (%)	SED/Hour outdoor	Mean time spent Outdoor (h)	Exposure ratio (%)
8/05/2010	10.69	3.53	33.0	1.58±0.52	6.75	25.2±8.3
15/05/2010	8.30	2.89	34.8	1.28±0.44	6.50	19.8±6.9
22/05/2010	9.80	3.27	33.4	1.47±0.49	6.67	21.2±7.1
Mean for mountain group	9.48	3.23	34.1	1.43±0.48	6.63	21.7±7.4
Cap dosimeter	10.36	3.19	30.8	1.56±0.48	6.62	23.7±7.2
Wrist dosimeter	8.65	3.16	36.5	1.30±0.46	6.63	19.8±7.3
Men	9.55	3.32	34.8	1.44±0.39	6.61	22.1±7.5
Women	9.39	3.26	34.7	1.41±0.49	6.65	21.3±7.6
Men with cap dos.	10.66	3.33	31.3	1.61±0.50	6.63	24.8±7.4
Women with cap dos.	10.02	3.29	32.8	1.52±0.50	6.61	22.4±7.5

Table 3 UVER exposures for two days (given in SED) measured using Viospor dosimeters and exposure ratio for the tennis players

	UVER exposure					
	Mean (SED)	Standard deviation (SED)	Coefficient of variation (%)	SED/Hour outdoor	Mean time spent outdoor 2 days (h)	Exposure ratio (%)
12,13/06/2010	10.36	1.90	18.3	1.48±0.27	7	12.3±1.6
19,20/06/2010	11.26	1.16	10.3	1.61±0.17	7	11.9±1.1
26,27/06/2010	10.32	1.83	17.8	1.47±0.26	7	11.4±2.0
Mean for tennis player group	10.65	1.57	14.8	1.52±0.22	7	11.9±1.5
Monitor dosimeter	10.36	0.85	8.2	1.48±0.12	7	12.0±1.9
Learning player dosimeters	10.74	1.78	16.6	1.53±0.25	7	11.8±1.5

Table 4 Runner UVER exposure for five days given in SED – measured using Viospor dosimeters for each subject for summer training period

		UVER exposure				
Subject	Mean time spent Outdoor 5 days (h)	Mean (SED)	Standard deviation (SED)	Coefficient of variation (%)	SED/hour outdoor	Exposure ratio (%)
1	7.67	4.38	5.52	126.0	0.66±0.89	1.83±2.29
2	7.10	2.47	0.74	29.9	0.35±0.13	1.17±0.36
3	8.08	8.03	7.27	90.6	1.08±1.09	3.62±3.23
4	7.52	3.17	1.71	53.8	0.44±0.23	1.43±0.78
5	7.72	3.37	0.54	15.9	0.44±0.07	1.46±0.22
Mean for all subjects	7.62	4.28	4.07	95.0	0.59±0.61	1.90±1.79