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ORIGINAL ARTICLE

Ultraviolet exposure of competitors during a Tokyo Olympic Sailing Regatta Test Event

José Vicente Gutiérrez-Manzanedo[1] | Carmen Vaz Pardal[2] | Nuria Blázquez-Sánchez[3] | Maria Victoria De Gálvez[4] | José Aguilera-Arjona[4] | Jose Luis González-Montesinos[1] | Francisco Rivas Ruiz[5] | Magdalena De Troya-Martín[3]

[1]Department of Physical Education, Faculty of Education Sciences, University of Cádiz, Cádiz, Spain

[2]Andalusian Centre for Sports Medicine, Cádiz, Spain

[3]Dermatology Service, Costa del Sol Hospital, Marbella, Spain

[4]Department of Dermatology and Medicine, Photobiological Dermatology Laboratory Medical Research Centre, Faculty of Medicine, University of Málaga, Málaga, Spain

[5]Research Unit, REDISSEC, Costa del Sol Sanitary Agency, Marbella, Spain

Correspondence
José V. Gutiérrez-Manzanedo, Department of Physical Education, Faculty of Education Sciences, University of Cádiz Avda, República Saharaui s/n, 11519, Puerto Real, Cádiz, Spain.
Email: josegu.manzanedo@uca.es

Abstract

Background: Overexposure to sunlight is the main cause of skin cancer. Photoprotection practices and sunburn play a crucial role in skin cancer prevention.

Objectives: This study aimed to quantify the risk of sun exposure and to evaluate photoprotection practices in Spanish sailors during Olympic competitions.

Methods: Solar daily ultraviolet (UV) radiation cycle, personal UV dosimetry, photoprotection practices and sunburn checking were followed during three consecutive days of competition among sailors from the Spanish Olympic Sailing Team during a Tokyo Olympic Regatta Test Event.

Results: A total of 13 sailors (7 women), with mean age of 27.6 ± 4.7 years and sports experience of 17.7 ± 5.4 years, were studied. The most common phototypes were type III (53.8%) and type II (38.5%). The rate of sunburn checked was high (46.2%). The mean daily personal UV exposure received was 761.0 ± 263.6 J/m^2, 3.0 ± 1.1 minimal erythemal dose and 7.6 ± 2.6 standard erythemal dose, seven times greater than the maximum permissible UV light exposure values for an 8 h working day. The use of a T-shirt was the most common practice (94.2%), followed by the use of shade (50.2%), hat/cap (44.0%), sunglasses (26.1%) and sunscreen (11.8%).

Conclusions: Olympic sailor's studies presented high levels of UV radiation received, high rate of sunburn and insufficient adherence to sun-protective behaviours (especially, to use of sunscreen) to prevent sunburn, the main cause of skin cancer. Sport Federations should develop educational campaigns addressing sun-related exposure habits and photoprotection behaviours to reduce the risk of skin cancer among these athletes.

KEYWORDS
Olympic sailors, skin cancer, standard erythemal dose, sun exposure radiation, sunburn

1 | INTRODUCTION

Skin cancer is one of the most common types of cancer worldwide and the rates are rising particularly rapidly.[1] Although sun exposure is a natural source of vitamin D, crucial to absorb the calcium in the bones, too much ultraviolet radiation (UVR) increases the risk of skin cancer.[2] Overexposure to sunlight is the main preventable cause of skin cancer.[3] Similarly, personal photoprotection behaviours such as staying at shade, wearing the cap, sunglasses and protective clothing, applying sunscreen and limit time exposure during midday sun are strongly recommended to reduce the risk of skin cancer.[4]

It is well-known that the population practicing outdoor sports is growing fast in the last years.[5] Sunlight exposure is an important component of outdoor sports.[6–10] Water sports present a potentially high UVR exposure because the sunlight exposure received directly from the sun adds to the reflected UVR from the open water surface[11] as well as the potentially damaging effect of this UVR in the wet skin by the lens effect of the water droplets. This condition, combined with practicing and a competitive schedule, with more than 8 h of daily sun exposure in spring and summer seasons, results in high rates of personal UVR exposure.

Some studies focus on self-reported sun exposure habits for skaters, golfers, cyclists, runners, surfers, windsurfers, kitesurfers, Olympic and Paralympic sailors, found high rates of sun exposure and sunburn among participants.[8,9,12–17]

However, few published studies have focused on solar exposure received by outdoor athletes using dosimeters to objectively measure personal exposure to UVR.[6,18–25] Personal dosimetry allows quantifying UVR received by the athlete during sport. These studies conducted with runners, cyclists, skiers, golfers, tennis players, hikers, triathletes and rowers, found personal sun exposure levels from 0.062 standard erythemal dose (SED) for marathon runners to more than 30 SED for triathletes during an Ironman.[6,18–25] Of these studies, just two[23,24] have been conducted with athletes in water sports, one to triathletes (during swimming, cycling and running stages)[23] and one to rowers.[24] Downs et al carried out research on personal solar ultraviolet exposure, measured using polysulphone film dosimeters, to triathletes during competitive Sprint, Olympic and Ironman events in Australia and New Zealand.[23] This research found personal exposure range from 0.2 to 6.8 SED/h, where the second highest stage exposure occurred during the swim (average = 28% exposure of any triathlon). Buxton et al conducted a study aimed to measure the real-time solar UVR exposure, measured using personal electronic dosimeters, on high school rowing students during the competition (56 races of 5 regattas).[24] The findings of this study showed a mean race UVR exposure of 1.15 SED and a mean race time of 46 min.

To date, no study has quantified solar UVR exposure using personal dosimetry to Olympic sailors during competition. Therefore, the aims of this study were to quantify the risk of sun exposure and to evaluate photoprotection practices among sailors from the Spanish Olympic Sailing Team during a Tokyo Olympic Regatta Test Event.

2 | MATERIALS AND METHODS

2.1 | Study design

This is an observational study in which was quantified the risk of sun exposure and evaluated sun protection practices among sailors from the Spanish Olympic Sailing during a Tokyo Olympic Regatta Test Event. Ambient solar UVR, personal UV dosimetry, photoprotection practices and sunburn checking were followed during three consecutive days of competition in Sagami Bay (Japan).

2.2 | Study participants

All 13 sailors from the Spanish Olympic Sailing Team for the 2020 Tokyo Olympic Games taking part in the Ready, Steady, Tokyo 2019 Olympic Sailing Regatta Test Event (official test event of the Tokyo 2020 Olympic Sailing Competition), held in Enoshima Yacht Harbour, Sagami Bay (35° 15′ 1“ N, 139° 25’ 1” E, sea level), Japan, from 15 to 22 August 2019, were invited to participate in this study. Sailors competed in classes RS:X Windsurf Men and Women, RS:X W, 470 Two Person Dinghy Men and Women, 49er FX Skiff Women, 49er Skiff Men, Nacra, Laser Radial One Person Dinghy Women. The participants were all qualifiers from the Spanish Sailing Team to participate in these classes for the 2020 Tokyo Olympic Games.

2.3 | Ambient UV exposure

The ambient daily cycle of UV index (UVI) during each day of the measurement period (from 18 to 22 August 2019) was recorded in harbor of Koshigoe (Japan) (35°18′29“ N 139°28’55” E, 15 m over sea level), the closest weather station (10 km) to Sagami Bay, the localization of sailing training and competitions. Data were provided from historical records for this localization from the web page of www.Worldweatheronline.com. Maximal daily UVI and UVI at intervals of 30 min from sunrise until sunset were obtained to calculate the accumulated effective erythemal dose for study volunteers during the competition days from 8 AM to 8 PM (local time).

2.4 | Study protocol

After reading the informative sheet and signing informed consent, all 13 sailors invited agreed to participate in the study. To assess personal UV dosimetry and sun protection practices, and to undertake sunburn checking during the competition days, in the presence of researchers all participants:

1. Carried a personal UVR dosimeter during three consecutive competition days. Based on the scheduled race time, nine athletes carried personal dosimeters from 18 to 20 August 2019 and four athletes from 20 to 22 August 2019, from

8 AM to 8 PM (local time). The timeline for a typical competition race day includes time for rigging boats, for reaching the race course (1 or 2 h before the scheduled starting time), for races, for waiting between races and for de-rigging boats (staying approximately 2 h after the last race). According to the recommendations,[26] sailors attached the dosimeter to the wrist.

The device used to measure the personal cumulative solar UV exposure was VioSpor blue line Type II dosimeter (Biosense Laboratory, Bornheim, Germany),[27] applied successfully in previous studies conducted with athletes.[6,19,20,25] This dosimeter is based on a biological film of spores covered by a filter system that simulates the erythematous response of the human skin. For use in water sports, the dosimeter is mounted in a waterproof casing with a diameter of 32 mm. The measurements as expressed as J/m^2, MED (minimal erythemal dose) and SED. The MED, equals 250 J/m^2 normalized to 298 nm, is the sunburn threshold dose in untanned skin Type II 24 h after sun exposure. The SED corresponds to 100 J/m^2 of erythemally weighted UVR. According to the manufacturer, the working range used is 0.4–22 MED (Type II) with a measurement error of 10%.

2. Completed a diary regarding photoprotection practices adopted (staying in shade, wearing a cap, sunglasses and protective clothing, and applying sunscreen) by an hour from 8 AM to 8 PM (local time) on every day of the 3 days of the measurement period, similarly to previous studies.[28,29]
3. Checked their skin on each of the 3 days of the measurement period. After the daily competition, a skin check was undertaken by a well-trained physician from the Royal Spanish Sailing Federation to identify sunburn. Sunburn was defined as the presence of reddening with or without pain or blistering, lasting at least 1 day, that blanches with pressure.

2.5 | Ethics

This study was approved by the Research Ethics Committee of the Costa del Sol Hospital on 17 June 2019. All the data collected in this project have been registered anonymously, strictly following the laws and protection regulations of data in force (Law 41/2002 of November 14; Law 15/1999 of December 15, EU Data Protection Regulation, 2016/679).

2.6 | Statistical analysis

Statistical analysis was performed using the SPSS version 23.0 statistical program for Windows. The descriptive analysis for qualitative variables was done by calculating frequencies and percentages and the statistical differences were analyzed by a non-parametric Chi^2 test from data in contingency tables. Quantitative variables were performed using measures of central tendency and dispersion (mean ± SD). Statistical significance was set at $p < .05$.

TABLE 1 Sociodemographic characteristics and sports experience among athletes participating in the study

Variable	Results *n* (%)
Gender	
Male	6 (46.6)
Female	7 (53.4)
Age (years) †	27.6 ± 4.7
Sport experience (years) †	17.7 ± 5.4
Skin color	
Very fair	0 (0.0)
Fair	5 (38.5)
Olive	7 (53.8)
Dark	1 (7.7)
Black	0 (0.0)
Skin phototype	
I	0 (0.0)
II	5 (38.5)
III	7 (53.8)
IV	1 (7.7)

†Indicates mean ± standard deviation.

3 | RESULTS

All 13 participants (7 women, 53.4%) carried out a personal dosimeter, completed the diary and were checked by a well-trained physician. Means of age and sporting experience were 27.6 ± 4.7 and 17.7 ± 5.4 years, respectively. The most common phototype was type III (53.8%), followed by type II (38.5%) (Table 1).

The maximal potential UVI in the sailing zone in Sagami Bay during the competition periods corresponds to the maximal UVI values of the year in summer. The ambient daily cycle of UVI during each day of the measurement period (from 18 to 22 August 2019) was recorded in harbour of Koshigoe (Japan) and the maximal UVI measured at midday was close to the maximal expected for the total clear sky for this localization at the date of competitions (Table 4). Four of the 5 days of study were partially cloudy with UVI peaks over 8, and the dosimetry in terms of solar pondered erythemal dose varied from 2031.6 J/m^2 in the cloudiest day to 4183.9 J/m^2 reached from 8 AM to 8 PM (local time). The sailors were potentially exposed from 20 to 41.75 SED or 8 to 16.7 MED (Table 2).

The Olympic sailors studied received a mean daily personal UV exposure on three consecutive competition days of measurement of 761.0 ± 263.6 J/m^2, 3.0 ± 1.1 MED and 7.6 ± 2.6 SED. While the cumulative daily erythemal doses for the athletes on these 3 days were 2282.9 ± 790.7 J/m^2, 9.1 ± 3.2 MED and 22.8 ± 7.9 SED (Table 3).

In terms of sun protection practices on the three consecutive competition days by hours, the athletes adopted unequal behaviours throughout the day. Use of a T-shirt was the most common practice (94.2%), followed by the use of shade (50.2%), use of hat/cap (44.0%), use of sunglasses (26.1%) and use of sunscreen (11.8%)

TABLE 2 Ambient solar ultraviolet radiation during each day of the measurement period

Date	Max UVI (Potential clear sky)	Max UVI Measured	Temperature Min/Max (°C)	Sky (Cloud level)	Total Daily Erythemal dose (J/m^2)	SED (100 J/m^2)	MED, Phototype II (250 J/m^2)	MED, Phototype III (300 J/m^2)
18 Aug 2019	9.2	8.0	30/34	Slightly Cloudy	4183.9	41.75	16.70	13.92
19 Aug 2019	9.8	8.3	29/33	Partly Cloudy	3698.7	37.00	14.80	12.33
20 Aug 2019	9.3	8.3	28/32	Partly Cloudy	3676.8	36.75	14.70	12.25
21 Aug 2019	8.8	7.9	27/30	Partly Cloudy	3356.2	33.50	13.40	11.17
22 Aug 2019	8.8	4.5	26/31	Cloudy	2031.6	20.25	8.10	6.75

Abbreviations: Aug, August; Max, maximum; MED, minimal erythemal dose; Min, minimum; SED, standard erythemal dose; UV, ultraviolet; UVI, ultraviolet index.

(Table 4). With regard to the reapplication of sunscreen, although 12 (92.3%) of the participants reported applying sunscreen every day of the three competition days, just four (30.8%) of the participants indicated re-apply sunscreen on these days.

The rate of sunburn during the three competition days checked by a well-trained physician was high, where six athletes (46.2%) had suffered at least one sunburn, while three (23.1%) of them had been sunburned twice. Sunburns were observed on the cheeks (four), lips (two), nose (one), neckline (one) and forearms (one).

4 | DISCUSSION

This study quantified the risk of sun exposure and evaluated photoprotection practices among all 13 sailors from Spanish Olympic Sailing Team during a Tokyo Olympic Regatta Test Event.

Ambient solar UVR during each day of the measurement period (from 18 to 22 August 2019) were recorded in harbour of Koshigoe (Japan). Our results showed a high level of ambient solar UVR, where four of the 5 days of the study reached UVI peaks over 8. According to WHO recommendations,[11] at UVI values of 8 and above the message that sun protection measures are needed should be reinforced (avoid being outdoors during midday hours, make sure you seek shade and must use a shirt, hat and sunscreen). In addition, in our study, the dosimetry in terms of solar pondered erythemal dose varied from 2031.6 to 4183.9 J/m^2 and the sailors studied were potentially exposed from 20 to 41.75 SED or 8 to 16.7 MED.

Personal UVR dosimetry data received for athletes studied showed strongly the high level of UVR received. Our results found a mean daily personal UV exposure for the athletes on the 3 days of measurements of 761 ± 263.6 J/m^2 or 7.6 ± 2.6 SED. This value obtained for sailors studied exceeded seven times the maximum personal exposure of 100–130 J/m^2 effective UV dose per 8 h period for sensitive unprotected skin, recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[30] and by the American Conference of Governmental Industrial Hygienists (ACGIH).[31] Moreover, the mean daily personal UV exposure for the athletes studied also exceeded three times the MED for persons with skin phototype II, which means that erythemal may be induced in these subjects if their skin is un-tanned.[30] Even some studies have demonstrated that at a suberythemal dose of UVB radiation causes significant DNA damage, which might predispose to skin cancer.[32,33]

The study results showed an insufficient adherence to sun protective behaviours during competition to prevent sunburn among sailors studied. Sailors reported high levels of the use of T-shirts and the use of hats. Although these practices are certainly appropriate, Sailing Federations need to ensure that both meet defined photoprotective criteria.[34] According to the Australian/New Zealand Standard for sun protective clothing, the ultraviolet protection factor ranting, which indicates how well the material blocks UVR from the sun, must reach a minimum of 15, being 30 and 50 or 50+, good and excellent, respectively.[34] On the other hand, sailors reported low rate of use of sunscreen SPF ≥15 and also reported very low

TABLE 3 Personal solar dosimetry during three consecutive competition days among athletes participating in the study

			Accumulated 1-day dose			Accumulated 3-day dose		
Test[a]	Protocol	Date	J/m^2	MED	SED	J/m^2	MED	SED
1401	1	18–20 Aug 2019	849	3,.4	8.5	2547	10.2	25.5
1744	2	18–20 Aug 2019	1068.3	4.3	10.7	3205	12.8	32
1301	3	18–20 Aug 2019	711.3	2.8	7.1	2134	8.5	21.3
1502	4	18–20 Aug 2019	1137.3	4.5	11.4	3412	13.6	34.1
1537	5	18–20 Aug 2019	791.3	3.2	7.9	2374	9.5	23.7
2024	6	18–20 Aug 2019	728	2.9	7.3	2184	8.7	21.8
1446	7	18–20 Aug 2019	757.3	3.0	7.6	2272	9.1	22.7
1274	8	20–22 Aug 2019	487.3	1.9	4.9	1462	5.8	14.6
2148	9	18–20 Aug 2019	839.3	3.4	8.4	2518	10.1	25.2
2350	10	18–20 Aug 2019	1159	4.6	11.6	3477	13.9	34.8
1362	11	20–22 Aug 2019	616	2.5	6.2	1848	7.4	18.5
2299	12	20–22 Aug 2019	261	1.0	2.6	782.9	3.1	7.8
1844	13	20–22 Aug 2019	487.3	1.9	4.9	1462	5.8	14.6
Mean			761	3.0	7.6	2282.9	9.1	22.8
SD			263.6	1.1	2.6	790.7	3.2	7.9

[a]Test with VioSpor® Blue Line Type II dosimeter (Biosense, Borheim, Germany).

Abbreviations: MED, minimal erythemal dose; SED, standard erythemal dose; Aug, August. SD, standard deviation.

TABLE 4 Sun protection practices by hours while competing

Time	Shade *n* (%)	Hat/cap *n* (%)	Sunglasses *n* (%)	T-shirt *n* (%)	Sunscreen *n* (%)
08:00–09:00	34 (87.2)	3 (7.7)	6 (15.4)	37 (94.9)	9 (23.1)
09:00–10:00	17 (43.6)	17 (43.6)	14 (35.9)	36 (92.3)	12 (30.8)
10:00–11:00	21 (53.8)	17 (43.6)	14 (35.9)	36 (92.3)	12 (30.8)
11:00–12:00	12 (30.8)	27 (69.2)	12 (30.8)	37 (94.9)	7 (17.9)
12:00–13:00	8 (20.5)	25 (64.1)	11 (28.2)	37 (94.9)	6 (15.4)
13:00–14:00	5 (12.8)	24 (61.5)	12 (30.8)	37 (94.9)	2 (5.1)
14:00–15:00	7 (17.9)	24 (61.5)	12 (30.8)	37 (94.9)	4 (10.3)
15:00–16:00	8 (20.5)	21 (53.8)	14 (35.9)	37 (94.9)	3 (7.7)
16:00–17:00	16 (41.0)	19 (48.7)	12 (30.8)	36 (92.3)	0 (0.0)
17:00–18:00	34 (87.2)	13 (33.3)	5 (12.8)	37 (94.9)	0 (0.0)
18:00–19:00	36 (92.3)	9 (23.1)	5 (12.8)	37 (94.9)	0 (0.0)
19:00–20:00	37 (94.9)	7 (17.9)	5 (12.8)	37 (94.9)	0 (0.0)
Overall	235 (50.2)	206 (44.0)	122 (26.1)	441 (94.2)	55 (11.8)

rate of reapplication of sunscreen. In our study, most of the participants did not re-apply sunscreen during competition days, where just one in three (30.8%) participants reported to re-apply sunscreen on these days, and this is the weakest point about sun-protective practices. This is possibly due to the conditions during a competition day are not favorable to re-apply sunscreen were carrying the sunscreen with you may be inconvenient and may even lose it. Some studies recommend taking oral antioxidants before UV exposure as a complementary measure to prevent damage to the skin.[35,36] Lastly, sailors studied reported a high level of the use of shade, however, also showed a very low rate of avoidance of midday sun (when shade is most needed) on competition days. International Sailing Events (i.e. Sailing World Cup Series, Olympic Sailing Competitions) are scheduled during midday sun and this became impossible for sailors to avoid peak UV exposure hours during competition. Therefore, it is crucial for these sailors to maximize the use of other sun protection measures (use of hat, sunglasses and protective clothes, application and re-application of sunscreen) during competition, especially during peak UV exposure hours. According to our results, previous studies have also shown low adherence to sun protective measures among recreational,[37] Olympic[8] and Paralympic sailors.[17]

In our study, the rate of sunburn checked by a well-trained physician during the three consecutive competition days was worryingly high, where nearly half (46.2%) of participants had suffered at least

one sunburn in the measurement period. The high rate of sunburn observed during three competition days among sailors studied combined with their high levels of sun exposure during many years of competition and practicing for a sports career, suggest that a large number of sunburns will be accumulated. This finding is very relevant since the presence and number of sunburns experienced for all-life periods are the main risk factor for cutaneous melanoma.[38] No study to date checked the skin of elite sailors to identify sunburn by a well-trained physician during a competition event. Previous studies conducted in water sports,[8,9,16,17,37] found a range from 76.7% to 84.7% of the athletes surveyed that reported having been sunburned at least one time during the last sporting season. By contrast, a recent study by Downs et al focused on the biologically effective solar UV likely to be received as a total dosage by gold medal competitors of 33 different outdoor sports (144 Olympic events schedule outdoors between 24 July and 9 August 2020) of the 2020 Tokyo Olympic Games, Olympic sailing was not estimated to be one of the outdoor sports with a highest expected erythemal effective solar UVR exposures during the 2020 Tokyo Olympic Games.[39] Olympic sailing resulted in a low estimate of solar UVR exposure because the short duration of the events analyzed, from 22 min for Mixed Multihull-Nacra 17 Foiling to 1 h 28 min for Laser Radial-One Person Dinghy.

Therefore, our findings regarding ambient solar UVR, personal UV sun exposure received sun protection practices and sunburns experienced highlight the need to apply effective measures to address the risk of skin cancer.

There were four main strengths in the current study. First, it was the first study that assessed personal sun exposure using dosimeters to quantify the risk of sun exposure among Olympic sailors. Moreover, in this study data were collected during competition in the same venue where Olympic Games are held. Second, our study was also the first study that checked the skin of elite sailors to identify sunburn by a well-trained physician during a competition event. Third, our study was undertaken with a solid methodology base using a multidimensional evaluation of the risk of skin cancer with four objective instruments for obtaining ambient solar UVR, personal UVR dosimetry, sun protection behaviours and rate of sunburn. And fourth, our study was conducted with elite athletes who are role models for others athletes and for society in general and are leading the promotion of healthy life. On the other hand, this study has several limitations. First, in this study, our cohort of elite athletes represented a small sample size, but they were all the sailors of the Spanish Olympic Sailing Team for the 2020 Tokyo Olympic Games. And second, although the timeline for a typical competition race day is similar for all Olympic sailors, our study was focused on sailors from the Spanish Olympic Sailing Team, therefore findings may be different to sailors from other countries.

5 | CONCLUSIONS

Olympic sailors studied presented high levels of UVR received, high rate of sunburn and insufficient adherence to sun-protective behaviours (especially, to use of sunscreen) to prevent sunburn, the main cause of skin cancer. Therefore, Sport Federations should develop educational campaigns addressing sun-related exposure habits and photoprotection behaviours, especially the use of sunscreen, and health surveillance programs to reach effective measures to reduce the risk of skin cancer among these athletes.

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CONFLICT OF INTEREST

The authors have no interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

José Vicente Gutiérrez-Manzanedo https://orcid.org/0000-0002-0621-0469
Maria Victoria De Gálvez https://orcid.org/0000-0002-5863-495X
José Aguilera-Arjona https://orcid.org/0000-0002-1911-111X
Magdalena De Troya-Martín https://orcid.org/0000-0003-1098-6195

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