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ORIGINAL PAPERS

Ultraviolet sun exposure and sun protection behaviors in outdoor rock climbers

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Abstract

Background Overexposure to sunlight and sunburn are the main preventable causes of skin cancer. Outdoor sports are associated with significant levels of sunlight exposure.

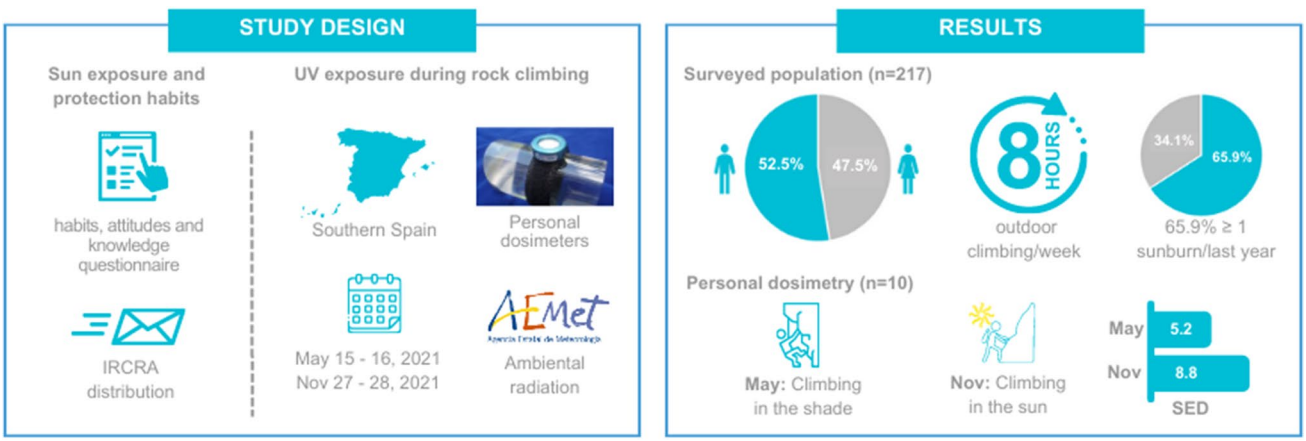
Aims We sought to quantify the sun radiation exposure received by outdoor rock climbers and assess their sun exposure habits, sun protection behaviors, attitudes, and knowledge regarding skin cancer.

Methods From April to June 2021, outdoor rock climbers contacted via email completed an online validated self-reported questionnaire on sun related habits, behaviors, attitudes and knowledge. As a pilot trial, ten participants wore a personal dosimeter during two outdoor climbing weekends in May and November 2021. Ambient ultraviolet radiation (UVR) was also recorded.

Results A total of 217 outdoor rock climbers (103 women), mean age 36.8 ± 8.8 years (range 20–70 years) and median climbing practice per week of 8 h (IQR 7.5) were studied. Two in three (65.9%) participants reported at least one sunburn event during the previous rock climbing season. Of the survey respondents, 49.3% reported using sunscreen with SPF ≥ 15, 47% wore sunglasses, and 14.3% indicated they reapplied sunscreen every two hours. The median personal UVR dose measured during the two outdoor climbing weekends analyzed was 5.2 (IQR 1.8) and 8.8 (IQR 1.1) standard erythemal doses, respectively.

Conclusions The high rates of sunburn, the elevated personal UVR measured and the clearly insufficient sun protection practices followed during rock climbing together with unsatisfactory attitudes towards tanning reveal the need to develop explicit sun protection campaigns and educational strategies to reduce the risk of skin cancer among the athletes studied.

Graphical abstract



Keywords Ultraviolet radiation exposure · Sunburn · Sun protection practices · Skin cancer · Rock climbers

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1 Introduction

Skin cancer has one of the highest incidences and mortality worldwide [1]. Globally, in 2020, over one million people were diagnosed with non-melanoma skin cancer (excluding basal cell carcinoma) and more than 300,000 people with melanoma skin cancer, accounting for 64,000 and 57,000 deaths, respectively [1]. Overexposure to sunlight and resulting sunburn are the main preventable causes of skin cancer. Athletes who train outdoors have the added hazard of solar exposure, which can increase the risk of skin cancer [2].

Sport climbing is gaining popularity as evidenced by the International Olympic Committee adding sport climbing to the program of the Tokyo 2020 Olympic Games and formally approving the proposal to include sport climbing at the Paris 2024 and Los Angeles 2028 Olympic Games [3]. In outdoor rock climbing, sun exposure is greater since this type of climbing is performed outdoors and above sea level. This sport is also characterized by intermittent sun exposure (especially on weekends). Since both total cumulative and intermittent ultraviolet radiation (UVR) exposure have been associated with skin cancer risk [4–6], outdoor rock climbers are at high risk.

Although some studies have examined sun exposure and skin cancer risk in different outdoor physical activities [7–15], only one recent study, conducted in Sacramento (California, USA), focused on outdoor rock climbers [16]. Park et al. evaluated the perceptions and behaviors of 202 rock climbers regarding sun protection and sunscreen use [16]. In this survey study, only 56% of the participants had used sunscreen in more than half of climbing sessions. They also found that although 62% of the study participants reported it was important to use sunscreen every two hours during outdoor rock climbing, 49% stated that they rarely/never reapply sunscreen during these sessions. Study participants reported greasiness and bulkiness as the main barriers to using sunscreen during outdoor climbing [16].

However, no study to date has quantified solar UVR exposure in outdoor rock climbers using personal dosimetry during their sport practice. Measurements of actual sun exposure of climbers at a training site can contribute to preventive behavior (i.e., climbing in the shade, better selection of climbing training schedule). Accordingly, this study was undertaken to quantify sun exposure radiation received by outdoor rock climbers and to assess their sun exposure habits, sun protection behaviors, attitudes and knowledge regarding skin cancer.

2 Materials and methods

2.1 Study design

A descriptive cross-sectional study was performed to quantify sun exposure risk and to evaluate sun exposure habits, sun protection practices, and sun-related attitudes and knowledge among outdoor rock climbers.

2.2 Participants

Outdoor rock climbers were contacted via email by the International Rock Climbing Research Association (IRCRA) to invite them to participate in this study.

2.3 Study protocol

From April to June 2021, all participants completed an online validated [17] and previously used [13, 15, 18] self-reported questionnaire on sociodemographic characteristics, skin cancer risk factors, Fitzpatrick skin phototype [19], sun exposure habits and sun protection practices in the last rock climbing season. The questionnaire also included questions about attitudes and knowledge related to sun exposure and skin cancer and barriers to sunscreen use.

2.4 Personal UVR exposure measurement

Ten rock climbers, who practice outdoor climbing throughout the year, were selected by convenience sampling as pilot study participants to wear a personal UVR dosimeter during two outdoor climbing weekends. A VioSpor Blue Line Type II dosimeter (Biosense Laboratory, Bornheim, Germany) [20] was used in a manner similar to previous studies [7–10, 15] to quantify the cumulative personal solar UV exposure. The athletes attached the dosimeter to their climbing helmet. The units of measurement were given by the manufacturer as J/m^2, standard erythemal dose (SED) and minimal erythemal dose (MED) for skin type III. One SED is equal to 100 J/m^2 of effective of UV erythematic radiation exposure. One MED corresponds to 300 J/m^2 normalized to 298 nm, the sunburn threshold dose in untanned skin type III 24 h after sun exposure. According to the manufacturer, the working range for a Type II dosimeter is 0.4–22 MED and the measurement error is 10% [20]. Therefore, a weekend in May and a weekend in November were chosen, when the UV index (UVI) values are the zenith and nadir of the year, respectively. Study participants were invited to freely choose the location and climbing time during selected weekends.

2.5 Ambient UVR exposure

The daily cycle of the ambient UVI for each of the four days of the measurement period was recorded from historical UVI data provided by the Spanish State Meteorological Agency. Maximum daily UVI and UVI at 30-min intervals

from sunrise until sunset were obtained to calculate the cumulative potential effective erythemal dose in the study volunteers on the training days. The potential effective erythemal dose and the effective dose in number of SEDs and MEDs for phototype III were calculated for climbing time. The exposure ratio (ER) between personal UVR measurement and potentially effective ambient UVR data was calculated for each study weekend and expressed as a percentage (personal UVR exposure measurement/potentially effective ambient UVR data × 100). Maximum temperatures at the study sites were taken from the meteorological stations from the Spanish Ministry of Agriculture.

2.6 Statistical analysis

The descriptive analysis for quantitative variables was performed using measures of central tendency, dispersion and position (median and interquartile range [IQR] in the event the variable was not normally distributed). Qualitative variables were analyzed by calculating frequencies and percentages. All analyses were conducted using IBM SPSS version 28.0.

3 Results

3.1 Sun-related questionnaire

The questionnaire was completed by 282 outdoor rock climbers. Of these, 65 (23%) did not complete the sunburn and/or sun protection practices sections and were excluded from the study. Finally, a total of 217 outdoor rock climbers were studied.

The average age of the participants was 36.8 ± 8.8 years (range 20–70 years) and 103 (47.5%) were women. The climbers surveyed were from 17 different countries, mostly from Spain (70.5%), followed by the rest of Europe (13.8%). The vast majority of participants had high school-college or university studies (79.3%) and almost half were married/partnered (47.9%). The most common skin phototypes were type III (47.9%) and type IV (23.3%). The median number of years of sport experience was 9.5 (IQR 14), and the median number of hours of sport practice per week was 8.0 (IQR 7.5) (Table 1).

Regarding of self-reported sun exposure habits in the previous season, 48.4% and 63.6% of the participants informed more than 90 days and three or more hours per day of sun exposure, respectively. In addition, 65.9% of the participants reported at least one sunburn event, and about one in five (20.7%) reported three or more sunburn events in the previous rock climbing season (Table 2).

The most common sun protection practices during the previous sporting season were use of sunscreen with SPF ≥ 15 (49.3%) and sunglasses (47%); the least common were use of long-sleeved shirts and long trousers (21.2%), wearing a hat or cap (31.8%) and avoiding midday sun (35.5%) (Table 2). With regard to sunscreen reapplication, although only a few (17.5%) of the participants reported "not reapplying", only one in seven (14.3%) indicated reapplying sunscreen "at least every two hours".

In terms of skin check habits, although over half (54.4%) of the participants reported "having ever visited a dermatologist", only one in ten (10.6%) had done so in the last year.

With regard to attitudes towards sun exposure and tanning, 50.7% of participants said that sunbathing makes them feel good, 48.3% reported they like being tanned, and more than one in three (36.4%) declared they like sunbathing. Concerning skin cancer awareness, three items had a degree of agreement above 80%, specifically for the statements: "It

Table 1 Sociodemographic characteristics and sport practice among rock climbers participating in the study ($n = 217$)

Variable	*n* (%)
Gender	
Male	114 (52.5)
Female	103 (47.5)
Age (years)	
Mean—SD	36.8 ± 8.8
Range	20–70
Birthplace	
Spain	153 (70.5)
Rest of Europe	30 (13.8)
South America and Central America	20 (9.2)
North America	12 (5.5)
Asia	1 (0.5)
Oceania	1 (0.5)
Level of education	
None—primary—secondary	45 (20.7)
High school–college/university	172 (79.3)
Partnership status	
Single	97 (44.7)
Married/Partnered	104 (47.9)
Divorced/Widowed	16 (7.4)
Sport experience (years)	
Median—IQR	9.5 ± 14.0
Sport practice per week (hours)	
Median – IQR	8.0 ± 7.5
Skin Phototype (Fitzpatrick)	
I	18 (8.4)
II	44 (20.5)
III	103 (47.9)
IV	50 (23.3)

SD standard deviation, *IQR* interquartile range

Table 2 Sun exposure habits, sun protection practices and sunburn in the previous season among rock climbers participating in the study (n = 217)

Variable	*n* (%)
Sun exposure (days)	
≤ 30	44 (20.3)
31–90	68 (31.3)
> 90	105 (48.4)
Sun exposure (hours/day)	
< 3	79 (36.4)
3–4	68 (31.3)
≥ 5	70 (32.3)
Sunburn episodes in the previous rock climbing season	
< 1	74 (34.1)
1–2	98 (45.2)
≥ 3	45 (20.7)
Shade	
Never—hardly—sometimes	119 (54.8)
Usually—always	98 (45.2)
Sunglasses	
Never—hardly—sometimes	115 (53.0)
Usually—always	102 (47.0)
Hat/cap	
Never—hardly—sometimes	148 (68.2)
Usually—always	69 (31.8)
Long-sleeved shirts/long trousers	
Never—hardly—sometimes	171 (78.8)
Usually—always	46 (21.2)
Avoidance of midday sun (11:00 h – 16:00 h)	
Never—hardly—sometimes	140 (64.5)
Usually—always	77 (35.5)
Sunscreen with SPF ≥ 15	
Never—hardly—sometimes	110 (50.7)
Usually—always	107 (49.3)

SPF skin protection factor

is worthwhile to use sunscreen" (85.2%), "I worry about getting skin cancer from the sun" (84.2%), and "I worry about burning when I sunbathe" (80.4%) (Table 3).

The most common reason for not using sunscreen was "Eyes get watery when sweating and fingers are greasy/sticky" (60%), followed by "Sunscreen has a lot of chemicals" (35.6%) and "I forget because it is not part of the equipment" (35.6%).

The average score on the ten-item sun-related knowledge questionnaire was 6.5 ± 2.2 points (out of a maximum 10 points). Three items had a correct response rate of less than 40%: "Dark clothing protects from the sun more than light-colored clothing" (19.4%), "Using sunscreen is the best way to protect yourself from the sun and prevent skin cancer" (30.9%), and "Getting at least one hour of sunshine a day is recommended to ensure adequate vitamin D levels" (37.8%) (Table 4).

Twenty-five (11.5%) participants reported a family history of skin cancer and seven (3.2%) had been diagnosed with skin cancer, two with basal cell carcinoma and three with melanoma.

3.2 UVR exposure

The first weekend took place in Grazalema (southern Spain, 36° 45′ N; 5° 21′ W, 753 m altitude) on May 15 and 16, 2021 from 15.00 h to 20.00 h where, due to high temperatures, the athletes freely chose perform the entire climbing session in the shade. The second weekend took place in Benaocaz (southern Spain, 36° 41′ N; 5° 26′ W, 614 m altitude) on November 27, 2021 from 13.00 h to 17.00 h and on November 28, 2021 from 11.45 h to 16.30 h where, due to low temperatures, the athletes freely chose to perform the entire climbing session out of the shade.

The maximum potential UVI in the climbing zone on May 15 and 16 corresponded to the maximum UVI values for the summer period of the year, with a mean peak value of 9.35 ± 0.07 for both days. Similar to the UVI, the mean

Table 3 Attitudes towards sun exposure among rock climbers participating in the study (*n* = 209)

Variable	Unfavorable *n* (%)	Favorable *n* (%)
I like sunbathing	76 (36.4)	133 (63.6)
I like being tanned	101 (48.3)	108 (51.7)
Sunbathing makes me feel good	106 (50.7)	103 (49.3)
I don't like using sunscreen	60 (28.7)	149 (71.3)
It is worthwhile to use sunscreen	31 (14.8)	178 (85.2)
At midday, I'd rather be in the shade than in the sun	46 (22.0)	163 (78.0)
I worry about burning when I sunbathe	41 (19.6)	168 (80.4)
I worry about the spots and wrinkles I might get from sunbathing	71 (34.0)	138 (66.0)
I worry about getting skin cancer from the sun	33 (15.8)	176 (84.2)
It's easy to protect yourself from the sun by wearing a hat and protective clothing	149 (71.3)	60 (28.7)

Table 4 Knowledge about sun exposure and skin cancer among athletes participating in the study ($n=217$)

Variable	Correct answers, *n* (%)	Incorrect answers, *n* (%)
The use of UVA-ray booths before age 30 increases the risk of melanoma (True)	163 (75.1)	54 (24.9)
Ultraviolet radiation causes accelerated skin aging and various forms of skin cancer (True)	193 (88.9)	24 (11.1)
By staying in the shade, we are not at risk from the effects of solar radiation (False)	161 (74.2)	56 (25.8)
Using sunscreen is the best way to protect yourself from the sun and prevent skin cancer (False)	67 (30.9)	150 (69.1)
Once the skin is tanned, it is not necessary to use sunscreen (False)	193 (88.9)	24 (11.1)
Infants younger than 1 year should not be placed directly in the sun (True)	153 (70.5)	64 (29.5)
Sun protection measures must be used when the UV index is greater than 3 (True)	174 (80.2)	43 (19.8)
Dark clothing protects from the sun more than light-colored clothing (True)	42 (19.4)	175 (80.6)
Getting at least one hour of sunshine a day is recommended to ensure adequate vitamin D levels (False)	82 (37.8)	135 (62.2)
Children should use sunscreen with an index equal to or greater than 30 (True)	179 (82.5)	38 (17.5)

maximum temperature was 33.6 ± 0.04 °C, which indicated extreme weather conditions for sport activities (Table 2). On November 27 and 28, weather conditions were more favorable for climbing practice under sun exposure, with a mean peak UVI value of 2.25 ± 0.07 at midday and a mean of maximum temperature of 13.05 ± 1.1 °C. The cumulative erythemal dose in the training periods was 4414 J/m^2, corresponding to 44.1 SED and 14.7 MED for phototype III, for the May weekend, and 1269 J/m^2, corresponding to 12.7 SED and 4.2 MED for phototype III, for the November weekend (Table 5).

In terms of personal UVR exposure measurement, the median personal UVR dose during the first outdoor climbing weekend ($n=10$) was 522.0 (IQR 183.0) J/m^2, 5.2 (IQR 1.8) SED and 1.7 (IQR 0.6) MED for phototype III. The median personal UVR dose measured during the second outdoor climbing weekend ($n=10$) was 885.5 (IQR 116.2) J/m^2, 8.8 (IQR 1.1) SED and 3.0 (IQR 0.4) MED for phototype III (Table 6).

The median ER of the athletes during the May weekend and the November weekend was 11.8% and 69.8%, respectively (Table 6).

4 Discussion

Outdoor sports are associated with significant levels of solar UV exposure and an increased risk of skin cancer [2]. To the best of our knowledge, this is the first study to quantify sun exposure radiation received and to assess sun exposure habits, sun protection behaviors, attitudes and knowledge regarding skin cancer among outdoor rock climbers.

The two training periods selected for the dosimetry study were indicative of the range of atmospheric conditions with the zenith and nadir of UVI that climbers can encounter in southern Spain throughout the year. In mid-May climbers can be exposed to solar UV conditions, normally under clear skies, with a mean maximum temperature of 33.6 ± 0.04 °C and mean UVI peak of 9.35 ± 0.07, corresponding to

Table 5 Ambient solar ultraviolet radiation during each weekend of the measurement period

Date	Max UVI Measured[a]	Max Temperature (°C)[a]	Sky (Cloud level)	Total Activity Erythemal dose (J/m^2)[b]	SED (100 J/m^2)[b]	MED,Phototype III (300 J/m^2)[b]
15–16 May 2021	9.35 ± 0.07[c]	33.6 ± 0.04[e]	Clear sky	4414[c]	44.1[c]	14.7[c]
27–28 Nov 2021	2.25 ± 0.07[d]	13.05 ± 1.1[e]	Clear sky	1269[d]	12.7[d]	4.2[d]

ED standard erythemal dose, *MED* minimal erythemal dose, *Nov* November

[a]Indicates mean ± standard deviation

[b]Indicates sum of 2-day dose

[c]Data calculated from registry of Spanish State Meteorological Agency station in Malaga (36° 43′ N; 4° 28′ W, 54 m altitude) at 150 km of the study location and same latitude

[d]Data calculated from registry of Spanish State Meteorological Agency station in Cádiz (36° 29′ N; 6° 15′ W, 2 m altitude) at 80 km of the study location and same latitude

[e]Data calculated from registry of Spanish Ministry of Agriculture station in Villamartin (36° 51′ N; 5° 38′ W, 54 m altitude)

Table 6 Personal solar dosimetry for two outdoor climbing weekends among rock climbers participating in the study (n = 10)

Subject ID	Test[a]	Protocol	Date	Cumulative 2-day dose			ER[b]
				J/m^2	SED	MED, (Phototype III)	%
009	1876	1	15–16 May 2021	522	5.2	1.7	11.8
022	1734	2	15–16 May 2021	450	4.5	1.5	10.1
037	1872	3	15–16 May 2021	465	4.6	1.6	10.5
082	1791	4	15–16 May 2021	489	4.9	1.6	11.0
118	1670	5	15–16 May 2021	585	5.8	2.0	13.2
131	1965	6	15–16 May 2021	450	4.5	1.5	10.1
137	1600	7	15–16 May 2021	755	7.5	2.5	17.1
184	2152	8	15–16 May 2021	630	6.3	2.1	14.2
193	2018	9	15–16 May 2021	687	6.9	2.3	15.5
206	1828	10	15–16 May 2021	522	5.2	1.7	11.8
	Weekend 15–16 May 2021 ($n = 10$)						
			Median	522.0	5.2	1.7	11.8
			IQR	183.0	1.8	0.6	4.1
009	1983	11	27–28 Nov 2021	1030	10.3	3.4	81.1
022	1788	12	27–28 Nov 2021	777	7.8	2.6	61.2
037	1763	13	27–28 Nov 2021	823	8.2	2.7	64.8
082	2040	14	27–28 Nov 2021	909	9.1	3.0	71.6
118	2020	15	27–28 Nov 2021	913	9.1	3.0	71.9
131	1942	16	27–28 Nov 2021	862	8.6	2.9	67.9
137	1773	17	27–28 Nov 2021	777	7.8	2.6	61.2
184	1897	18	27–28 Nov 2021	917	9.2	3.1	72.2
193	1951	19	27–28 Nov 2021	921	9.2	3.1	72.5
206	2374	20	27–28 Nov 2021	810	8.1	2.7	63.8
	Weekend 27–28 Nov 2021 ($n = 10$)						
			Median	885.5	8.8	3.0	69.8
			IQR	116.2	1.1	0.4	9.1

[a]Test with Viosport® Blue Line Type II dosimeter (Biosense, Borheim, Germany). [b]Indicates median. MED: minimal erythemal dose; SED: standard erythemal dose; Nov: November; SD: standard deviation; IQR: interquartile range. ER: personal ultraviolet radiation exposure/ambient ultraviolet radiation exposure, expressed as a percentage

extreme UV conditions involving a cumulative erythemal dose of 44.1 SED, equivalent to 14.7 MED for phototype III, over the range of training hours of the study. In contrast, climbers may find more favorable ambient conditions towards the end of November, with a mean maximum temperature during training of 13.05 ± 1.1 °C and mean UVI peak of 2.25 ± 0.07, leading to total training time exposure of 12.7 SED, equivalent to 4.2 MED for phototype III.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) [21] and the American Conference of Governmental Industrial Hygienists (ACGIH) [22] recommend a maximum personal exposure of 100–130 J/m^2 effective UV dose per 8-h period for sensitive unprotected skin. In our study, the climbers' personal dosimetry results showed a high level of UVR received. By weekend, the median of 10 dosimetry readings was 522.0 (IQR 183.0) J/m^2, 5.2 (IQR 1.8) SED and 1.7 (IQR 0.6) MED for phototype III for the first weekend and 885.5 (IQR 116.2) J/m^2, 8.8 (IQR 1.1) SED and 3.0 (IQR 0.4) MED for phototype III for the second weekend. The values for both weekends were, respectively, between almost two and three times higher than the maximum personal exposure recommended [21, 22], which, therefore, means that erythema can be induced in individuals with skin phototype III if their skin has not been previously tanned [21]. Although the values of our pilot study are lower than those obtained in other outdoor sports such as triathlon [11, 23], cycling [7] or sailing [15], they are a cause for concern especially considering that during the first weekend, the athletes freely chose to perform the entire climbing session in the shade due to high temperatures. Contrary to expectations, the personal UVR exposure received by the athletes measured by personal dosimetry was higher during the second outdoor climbing weekend, in November, than during the first outdoor climbing weekend, in May. This difference resulted from the athletes freely choosing to perform the entire climbing session in the shade

due to high temperatures in the May period, and also freely choosing to perform the entire climbing session out of the shade due to low temperatures in the November period. In this respect, this study was carried out under real outdoor climbing conditions; the ethical commitment of the research was to respect and observe without interfering with the usual climbing practice. The athletes studied were free to choose the lengths and times and shade coverage of the hikes during all the climbing sessions analyzed. In this context, however, it is important to note that the results from the two climbing weekends do not represent the real-world behavior of rock climbers during climbing sessions throughout the year.

In our pilot study, the median ER for the outdoor climbing weekend in May in the shade and for the outdoor climbing weekend in November out of the shade was 11.8% and 69.8%, respectively. Sport practice in the shade with protection from high UVR and high temperatures led to a lower ER (11.8%) during training hours in the May period. However, despite good outdoor temperatures in the November period, training under solar exposure led to a higher ER (69.8%). Due to the dose received by the participants in November, the results indicate that additional sun protection (clothing, sunscreen) is needed for sport practice even in the autumn and winter seasons. These findings show that staying in the shade is a very effective measure to reduce the amount of UVR received by the athletes even in situations of extreme environmental irradiance. Studies of outdoor athletes have reported variations in ER values ranging from 3 to 26% for tennis players [9], 2 to 33% for runners [24], 17 to 35% for rowers [12], and 3 to 50%, 15 to 50% and 11 to 38%, for the swim, cycle and run stage, respectively, in triathlon competitors [11]. Body movement in sport practice and the angle of light incidence on different body parts are involved in this variation in ER values. Thieden et al. [25], using UV biological dosimeters such as those used in this work, demonstrated that the UV received by the head or shoulders is almost double that received by the wrist. Areas of the body positioned more perpendicular to the sun's rays during sport practice can reach ER rates of up to 90% [26].

Sunburn and sunlight exposure are the main factors for skin cancer [27]. In our study, the sunburn rate reported by climbers was high; around two of three (65.9%) participants surveyed reported at least one or more sunburn episodes during the last rock climbing season. These findings coincide with the results of previous studies carried out in other outdoor sports [13, 14, 28, 29]. Our findings are very worrying, also considering that in our study about two thirds (63.6%) of the participants reported more than 90 days of sun exposure during the last sporting season and a median sport experience of about 10 years. The sunburn episodes reported occurred during rock climbing practice. Any additional sunburn episodes related to leisure or work activities are not included. Consequently, the risk of skin cancer and especially the risk of melanoma (the most serious skin cancer with the highest risk of death) among the athletes studied is very high.

According to the World Health Organization [30], skin damage from solar UVR is largely avoidable if certain precautions are taken, such as using shade wisely, wearing protective clothing, applying and reapplying sunscreen and limiting time in the midday sun. In our study, the sun protection practices used by the athletes studied during the previous sporting season were clearly inadequate. The least effective sun protection practices to avoid sunburn (use of sunscreen and sunglasses) were the most common, while the most effective (use of shade, avoiding midday sun and wearing protective clothing) were the least common. Regarding reapplication of sunscreen, just one in seven (14.3%) participants indicated reapplying sunscreen at least every 2 h. As the main barriers to sunscreen use during outdoor climbing, the respondents commented that sunscreen is irritating to the eyes and makes fingers greasy (60%), has a lot of chemicals (35.6%) and is forgotten because it is not part of the equipment (35.6%). In addition, participants reported deficient skin check habits, with just one in ten (10.6%) stating having had their skin checked by a dermatologist in the last year. This low annual skin examination rate reveals a low perception of risk and requires awareness strategies that promote skin screening as a part of a comprehensive early detection strategy. These findings are similar to those reported by Park et al. [16] in a study conducted in the USA focused on sun protection knowledge and behavior in outdoor rock climbers, in which 56% of the participants had used sunscreen in more than half of the climbing sessions (49% reported rarely/never reapplying sunscreen), and greasiness and bulkiness were reported as the main barriers to sunscreen use. Similarly, a review published in 2013 by Jinna and Adams [31] described "lack of availability", "forgetting to apply" and "hinders sport performance by making hands slippery, giving extremities a greasy feel, burning their eyes" as the main barriers to sunscreen use. Our findings suggest that sun protection practices and skin examination habits (yearly skin screenings by a dermatologist) must be improved to prevent skin cancer in this young and at-risk group. Specific sunscreen products with a better texture for use by outdoor climbers should also be developed by the cosmetics industry. Oral antioxidant supplements have also been shown to be complementary to topical sun protection [32, 33].

Some studies [34] show that attitudes towards tanning and knowledge about skin cancer are important to prevent sunburn and skin damage. In our study, although a large majority of the participants reported being worried about skin cancer, almost half had unsatisfactory attitudes towards tanning, which coincides with the results of previous studies of outdoor sports athletes [13, 14]. Attitudes towards tanning are one of the main barriers to adopting appropriate

sun protection behaviors. While the participants presented an acceptable level of knowledge about sun exposure and skin cancer, this level was low compared with that of other groups of athletes [14, 35], especially considering that in our study, most of the participants reported having university studies. Also of note is the particularly low rate of correct responses to items concerning sunscreen and vitamin D, which can lead to deliberate sun exposure and improper use of sunscreen and other sun protection measures.

Our study has some limitations due to the study design and the self-report nature of the survey. First, our study data were collected using a self-report questionnaire and therefore could be subject to recall or social desirability bias. In fact, data are conflicting as many studies have found people to be inaccurate reporters [36, 37]. Second, in the dosimeter portion of study, a convenience sampling with a small size was used, thus selection bias could be present and our findings may differ with regard to other samples. And third, other studies [38] suggest that self-reported sunburn may be underestimated. Nevertheless, this study has two main strengths. This is the first study to quantify sun exposure radiation in outdoor rock climbers using objective personal dosimetry devices and to assess their sun exposure habits, sun protection behaviors, attitudes and knowledge regarding skin cancer. Two robust instruments were used, an objective personal dosimeter device [20] to quantify personal UVR received, used similarly in previous studies [7–10, 15] and a validated self-report questionnaire [17] widely used in outdoor sports settings [13–15, 35].

5 Conclusion

The high rates of sunburn, the elevated personal UVR measured and the clearly insufficient sun protection practices followed during rock climbing, together with unsatisfactory sun tanning attitudes, reveal the need to develop explicit sun protection campaigns and educational strategies to reduce the risk of skin cancer among the athletes studied.

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

Declarations

Conflict of interest On behalf of all the authors, the corresponding author states that there is no conflict of interest.

Ethical approval This study was approved by the Costa del Sol Hospital Research Ethics Committee on January 28, 2021 (num. 103-01-2021). In addition to the questionnaire, informed consent was obtained from the participants. All the data collected in this project were recorded anonymously, in strict accordance with current data protection laws and regulations (Law 41/2002 of November 14; Law 15/1999 of December 15, EU Data Protection Regulation, 2016/679).

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