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ORIGINAL ARTICLE

Skin cancer prevention in extreme sports: Intervention in a 24-h race

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Abstract

Introduction: Excessive sun exposure and sunburns are the main preventable causes of skin cancer. The growing popularity of outdoor sports in developed countries has motivated the objective of this work to study the risk of photoexposure and the skin cancer prevention needs of athletes in an extreme race and evaluate an intervention targeted at this population.

Methods: An observational study was conducted during the XXIII edition of the 101 km *de Ronda* race, which consisted of trail running and mountain biking categories. Environmental and personal dosimetry, monitoring of meteorological conditions, evaluation of the athletes' photoprotection and skin examination habits, a dermatological checkup, and a satisfaction questionnaire were performed.

Results: The ultra-endurance race was carried out under adverse conditions (maximum ultraviolet index (UVI) = 9.2, temperatures above 30°C, and relative humidity >35%). The mean effective erythema dose received by race athletes ($n = 11$) was $2959.2 \pm 404.2\ J/m^2$, equivalent to 29.6 standard erythema doses (SED). The CHACES questionnaire ($n = 1145$) showed a sunburn rate of 58% and poor protective habits: 62.9% of athletes do not usually use sunscreen and 67.2% do not self-examine their skin. Actinic keratoses (4.7%) and suspicious skin cancer lesions (4.2%) were found in dermatologic screening exams ($n = 170$). On the satisfaction questionnaire ($n = 111$), this intervention was rated as excellent (95.5%).

Conclusion: This research highlights the extreme risk of photoexposure that athletes are subjected to during ultra-endurance competitions. In the same way, it shows the need to carry out interventions aimed at the acquisition of healthy photoprotection habits and skin surveillance in this target group.

KEYWORDS
athletes, skin neoplasms, standard erythema dose, sun exposure, sunburn, thermal stress

1 | INTRODUCTION

The incidence of skin cancer in developed countries has been steadily rising in recent decades. The incidence of melanoma, which has a more comprehensive record than keratinocyte carcinomas, increased 320% in the USA since 1975[1] and 140% in the UK since 1990.[2] In Spain, the incidence of melanoma tripled between 1978 and 2002.[3] This increase appears to be slowing, but estimates still predict a rise in incidence in upcoming years.[4]

Excessive sun exposure and sunburns, in particular, are the main preventable causes of skin cancer; it is estimated that more than 80% of skin cancers are preventable.[5] Although there is strong or moderate evidence that physical activity is a preventive factor for the onset of numerous types of cancer (breast, lung, colon, kidney, bladder, and endometrial cancer, among others) and increased life expectancy among cancer survivors,[6] there is evidence that intense outdoor physical activity is associated with greater risk of melanoma.[7] Furthermore, a recent investigation identifying the sociological underpinning of skin cancer included outdoor sports as a cultural factor associated with a greater risk of skin cancer.[8] Outdoor athletes, especially those in long-duration disciplines, are exposed to the harmful effects of solar radiation. Acute sun exposure and intermittent radiation exposure, such as that which occurs during long-duration amateur sports events, have been associated with the onset of most melanoma and basal cell carcinoma (BCC), whereas chronic exposure, such as that which occurs during professional or continued outdoor sports, is associated with the onset of actinic keratosis and squamous cell carcinoma (SCC).[9,10]

More recent systematic reviews on sun exposure in outdoor athletes confirm the above data and encourage clinicians to conduct personalized assessments and provide educational support on photoprotective strategies as well as the use of mobile phone apps or personal dosimeters in these initiatives.[11,12]

In light of the growing popularity of outdoor sports as entertainment, there has been increased interest in evaluating the sun exposure these athletes are exposed to during competitions and training[13] as well as their habits, attitudes, and knowledge regarding sun protection.[14,15] Publications to date demonstrate that athletes are exposed to high rates of ultraviolet (UV) radiation[16,17] and have very deficient photoprotective habits.[18,19] Therefore, there is a need for novel interventions in this vulnerable population. In addition, among outdoor sports events, there has been a proliferation of sports competitions that are extreme, either due to their duration, course, or climactic conditions. In Spain, a country with very high UV radiation levels for more than six months of the year (from April to October),[20] many ultra-endurance challenges are held during the time of year of peak UV radiation.

In the present work, we study the risk of photoexposure and skin cancer of the participants in one of the most extreme and popular sports events in Andalusia (Spain), the *101 de Ronda race*. Specifically, we aim to (1) determine the amount of environmental and personal effective UV radiation that athletes are exposed during competition; (2) describe the habits, attitudes and knowledge in skin cancer prevention of the participants; (3) describe the actinic lesions found on the skin of athletes; (4) evaluate the satisfaction of the participants with a pilot intervention in the prevention of skin cancer.

2 | MATERIALS AND METHODS

A descriptive, cross-sectional, observational study was performed on-site during the XXIII edition of the *101 de Ronda* race.

2.1 | Characteristics of the race

This extreme race, which has mountain biking (MTB) and trail running categories, entails a circular, 101-km route and has a maximum duration of 24 h. The race takes place along natural mountain trails with little vegetation, through towns in the *Sierra de Ronda* (Spain), combining mainly dirt and few paved surfaces. The race route had sections between 400 and 900 m above sea level and had approximately 2800 m of accumulated elevation gain (Figure S1). In addition, this race is held during the months of maximum ultraviolet radiation and temperature in Spain. Indeed, this edition was held on May 14, 2022 starting at 9:30 AM for cyclists and 10:00 AM for runners. Maximum race completion time was 10.5 h for cyclists and 24 h for runners. Demographic information including age, gender, and sport modality of competition of all registered participant were collected by the race organizers.

2.2 | UV radiation exposure risk evaluation

Incident UV radiation during the race was determined via environmental dosimetry at a point along the course and the effective radiation dose received by athletes participating in the race was determined through personal dosimetry recorded with biological dosimeters.

- Environmental dosimetry. Solar UV radiation was measured at a fixed point on the course that was located in Ronda (36°46′4.638″N 5°9′11.423″W) (Figure S1B). A multisensory platform connected to an Arduino micro-controlled data logger was used for UV (erythematic), UVA (320–400 nm), temperature, humidity, and atmospheric pressure measurements and data collection at 5-min intervals. The erythemal irradiance sensor was based on a GUVB-T11L photodiode (Aluminum gallium nitride-based material) with a spectral response from 230 to 320 nm. The highest relative responsivity covers from 275 to 300 nm followed by a decay similar to that of the action spectrum for erythema and included in an aluminum case covered with a 1 mm teflon diffuser 1 mm layer. The UVA sensor is based on a GUVA-T11L full UV sensor with a relative

responsivity from 250 up to 375 nm. The sensor is included in an aluminum case and covered by a 2 mm 330 nm Schott filter and 1 mm teflon diffused filter for measurements on the range (320–400 nm). Both sensor units were intercalibrated with a Macam SR-9910 V7 double monochromator spectroradiometer (Irradian, Co. Scothland, UK) in the range from 290 to 400 nm against a 300 W Oriel solar simulator (Newport, Nebraska, USA). Spectroradiometer was calibrated in the Aerospatial National Institute of Spain against a calibrated quartz halogen lamp. The calibrated device/data logger is a research prototype from the Photobiology Laboratory of the Medical Research Center of the University of Málaga (Figure S1C).

Erythemal radiation was calculated by convoluting the solar simulator irradiance at 1 nm wavelength interval in the range of 290–400 nm and with respect to the erythemal action spectrum. Total erythemal irradiance corresponded to the integral in the interval 290–400 nm). The UVA radiation for UVA sensor calibration was calculated by the integral of the solar simulator irradiance between 320 and 400 nm in terms of W/m^2. Accumulated erythemal dose for SED was calculated from erythemal irradiance at 5 min intervals along the day. UV Index (UVI) was calculated from erythemal irradiance by multiplying for 40 according to OMS recommendation and as also interpretation of UVI values in terms of photoprotection needs.[21]

- Personal dosimetry. Twelve athletes, in the MTB ($n=6$) and trail running ($n=6$) categories, were selected by convenience sampling to wore personal biological dosimeters on the helmet or the shoulder, respectively. Athletes registered for the race, trail running and MTB clubs were contacted by email presenting the research study and asking for participation as volunteers. VioSpor® blue line Type III sensors, manufactured by Biosense (Bornheim, Germany) were used. They are based on immobilized spores whose highly sensitive DNA molecules produce a response profile that corresponds with that of the human skin for triggering sun burns.[22] This film is covered by a filter system with optical properties that simulate the erythema response of the human skin, in accordance with the reference erythema action spectrum described in ISO/CIE 17166:2019.[23] According to the manufacturer technical information,[24] the reproducibility of the equipment's data ranges between 5% and 20% (depending on the dose). The measurement is expressed as a sunburn threshold dose (J/m^2; MED; SED).

2.3 | Evaluation of photoprotective and skin examination habits

- Questionnaire on habits, attitudes and knowledge related to sun exposure (CHACES, for its initials in Spanish). An invitation to complete the CHACES questionnaire was sent by the organization to all athletes registered for the race. The questionnaire consisted of 42 item groups into the following sections: (1) Demographic data (12 items), (2) Skin color (1 item), (3) Fitzpatrick Sun reactive skin type (1 item), (4) Sun exposure habits (6 items), (5) Sunburn in the last year (1 item), (6) Sun protection practices (9 items), (7) Attitudes related to sun exposure (10 items), (8) Knowledge related to the sun and skin cancer (10 items). The validity of this questionnaire was demonstrated in the first phase of the analysis by the Cronbach α values obtained, which ranged from 0.45 to 0.8 for all components except knowledge (0.335). In the second phase, test–retest reliability was demonstrated (absolute agreement >60%). The questionnaire was completed through the SurveyMonkey platform. This questionnaire was created and validated[25] by our research team and used in previous studies in athletes.[26,27] Specific questions related to participation in the race, barriers to the use of sunscreen and skin examination habits were added to the original questionnaire.

2.4 | Evaluation of a pilot skin cancer awareness and prevention action

- Topical sunscreen for all participants. A health promotion action was performed for all athletes participating in the race that consisted of encouraging the use of topical sunscreen and its reapplication during the race. For this, single-dose samples of SPF 50+ sunscreen were included in the runner's gift bag and sunscreen dispensers were placed along the race's water stations.
- Dermatologic screening exams. A team of more than 20 specialists in dermatology, sports medicine, and nursing traveled to where the race was held to perform free, voluntary skin examinations for all athletes who wished to participate while race numbers were being collected (the day before the race). Groups of three professionals, one from each discipline, performed a comprehensive examination (head, trunk, upper, and lower limbs) using a dermatoscope (Dermlite DL100) and a Wood's light (Dermlite Lumio 2).
- Skin cancer registry. A skin cancer questionnaire was completed by health personnel during each examination. It included skin cancer risk factors and a personal and family medical history; the main findings were recorded. Athletes who had lesions suspected of being malignant were urged to visit their health center, as they were individuals outside of the Costa del Sol Hospital's healthcare district.
- Recommendations on photoprotection and skin self-examinations. After completing the examination, each athlete received personalized recommendations on healthy sun exposure, photoprotective measures, and skin self-examination techniques for the early detection of skin cancer from nursing department personnel. Likewise, a pamphlet with the main recommendations and samples of sunscreen were given to the athletes.
- *Satisfaction questionnaire*. Once this intervention was completed (skin screening, risk factors registration and personalized recommendations), the participating athletes were invited to voluntarily complete a satisfaction questionnaire implemented in SurveyMonkey platform scanning a QR code. Questionnaire consisted of three items scored via a four-point Likert scale.

2.5 | Ethical aspects

The study was approved by the Costa del Sol Research Ethics Committee in May 2022 (Study code: 002_May22_PI - CHACES 101). All data gathered were recorded and stored anonymously in strict compliance with all applicable data protection and confidentiality laws and regulations (Law 41/2002, of November 14; Organic Law 3/2018, of December 5, on personal data protection and guarantee of digital rights). All participants signed an informed consent form before participating. The data that support the findings of this study are available from the corresponding author upon reasonable request.

2.6 | Statistical analysis

A descriptive analysis was performed using measurements of central tendency, dispersion, and position for quantitative variables and distribution of frequency for qualitative variables. Statistical significance was established as $p < .05$. Statistical analyses were performed using IBM SPSS Statistics (version 22.0 for Windows, IBM Corp.) and graphics were created in GraphPad Prism (version 7.04 for Windows, GraphPad software).

3 | RESULTS

3.1 | UV radiation exposure risk evaluation

The XXIII edition of the *101 de Ronda* race took place from 9:00 AM on May 14, 2022 to 10:00 AM on May 15, 2022. The device located in the town of Ronda during the race recorded mainly clear skies, temperatures between 21° and 35°C (Table S1), humidity between 35% and 55%, and a maximum UVI of 9.2 at 2:38 PM. The UVI profile from May 14 (Figure 1A) showed the mean UVI values were at least moderate—greater than 3 requiring protection—during 7 h from 11:00 AM to 6:00 PM. It is also remarkable that very high levels —greater than 8— were reached from 1:00 PM to 4:00 PM. A total of 39.1 SED were accumulated during the sun cycle on the race day (Table S1), with a maximum of 6.2 SED/hour between 2:00 PM and 4:00 PM (Figure 1B).

Twelve athletes participated in the personal dosimetry measurements: six cyclists and six runners (Table 1). Data from eleven of them were analyzed because one of the runners did not finish the race. The mean effective radiation recorded by the race cyclists' dosimeters was 2908.3 J/m^2 (SD: 518.4), which is equivalent to 29.1 SED and 11.6 MED in a mean race time of 7.6 h (range: 5.2–9.5 h). The mean value for runners was 3020.2 J/m^2 (SD: 253.0), 30.2 SED, and 12.1 MED, in a mean race time in the sun of 11.5 h out of a total mean race time of 21.2 h, given that part of its competition takes place at night.

3.2 | Evaluation of photoprotective and skin examination habits

This edition of the race had 8904 participants, of which 90.6% were men. The mean age was 46 years and the majority (63.0%) of participants competed in the trail running category. The CHACES questionnaire was completed by 1181 athletes who registered for the race, a response rate of 13.3%. A total of 1145 (97%) questionnaires were analyzed after excluding those which did not answer the question about sunburns in the previous year or at least one answer in the sun protection habits and attitudes sections. A total of 78.8% of individuals who responded to the questionnaire were men, the mean age was 47.1 years (SD: 8.6), and 72% competed in the trail running category. Women and runners had a greater response rate to the CHACES questionnaire compared to the total number of race participants. In regard to skin type, the results show that nearly

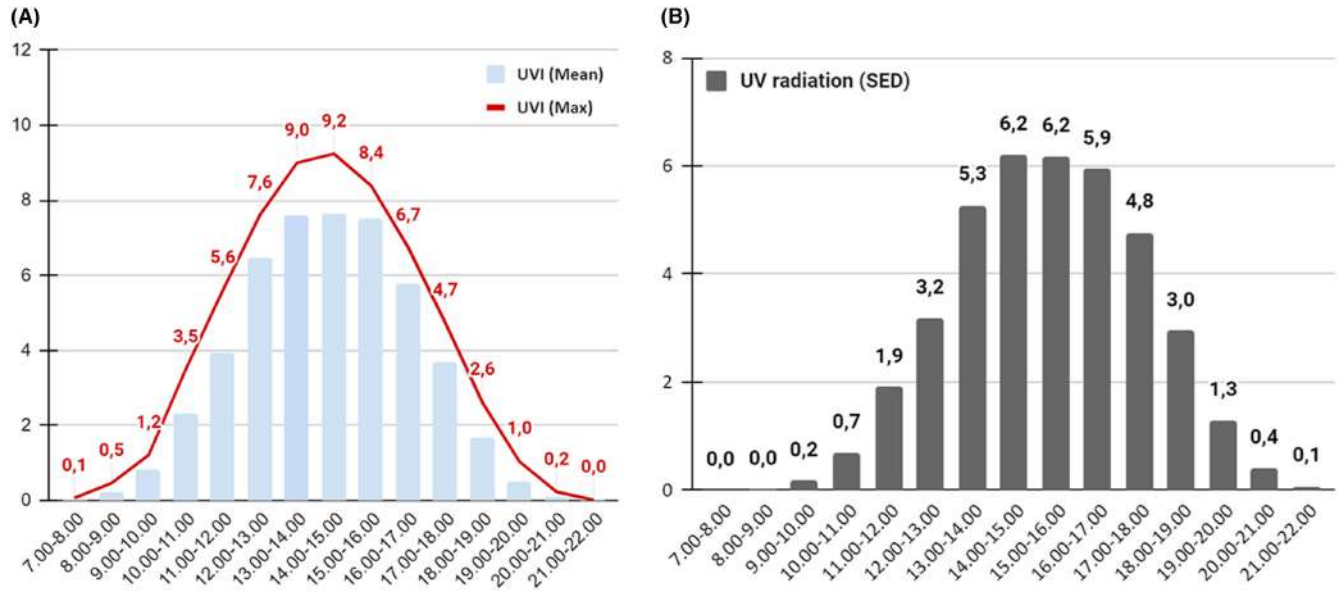

FIGURE 1 Ambiental dosimetry during sun cycle on the day the race was held May 14, 2022. (A) Mean and maximum UVI values and (B) standard erythema doses (SED) calculated by hour.

TABLE 1 Personal dosimetry among athletes participating in the study.

Modality	*n*	Dosimeter placement	Race duration (hours)	Sun exposure duration (hours)	J/m^2		SED (100 J/m^2)		MED Phot II (250 J/m^2)	
			Mean [Range]	Mean	Mean [Range]	SD	Mean	SD	Mean	SD
Cyclists	6	Helmet	7.6 [5.2–9.5]	7.6 [5.2–9.5]	2908.3 [2130–3465]	518.4	29.1	5.2	11.6	2.1
Runners	5	Shoulder	21.2 [16–22.8]	11.5[a]	3020.2 [2690–3248]	253.0	30.2	2.5	12.1	1.0

Note: Cyclists' start time: 9:30 AM. Runners' start time: 10:00 AM. Maximum race completion time was 10.5 h for cyclists and 24 h for runners.

Abbreviations: MED, minimum erythema dose; Phot, phototype; SD, Standard deviation; SED, Standard erythema dose.

[a]All the runners were exposed to 11.5 h of UV radiation until sunset, after that competition continued in the darkness of the night.

one-third (32.7%) of athletes identified their skin as light or very light and 23.6% of athletes classified their skin as sensitive or very sensitive (I-II) to UV radiation (Table 2).

In regard to sun exposure habits, it was observed that doing outdoor sports was a common habit among race participants who responded to the questionnaire, with 67.4% doing sports outdoors more than 90 days/year and 39.4% doing sports for more than 3 h per day. Likewise, it was observed that sunburns are frequent among the athletes surveyed: 58% (95% CI: 55.1%–60.9%) reported having at least one sunburn in the previous year and 17.8% reported having three or more sunburns (Table 2).

The results of questions related to photoprotective practices (Figure 2A) showed that around 50%–60% of athletes habitually wear sunglasses, wide-brimmed hats, and avoid the middle hours of the day when doing outdoor activities. The least common practices were the use of covering clothing (7.5%) and using shady areas (26%). The use of sunscreen reported by the athletes was low. Indeed, only 37.1% use it habitually, although 90.7% of athletes stated they used high sun protection factor (SPF) sunscreen (SPF ≥30) and 57.6% re-applied. The main barriers to implementation of the use of sunscreen (Table S2) reported were forgetting (58.1%), financial cost (34.2%), and an uncomfortable sensation when doing sports (31.3%).

The sun-related attitudes described by the athletes (Figure 2B) were mainly favorable toward skin cancer prevention, as more than 75% of those surveyed agreed or very much agreed with protective attitudes (from attitude 5 to attitude 10 in Figure 2B), and less than 25% did not like using sunscreen. However, risky attitudes such as enjoying sunbathing and being tan were attitudes with which 41.8% and 52% of those surveyed agreed with, respectively.

The mean percentage of correct answers on the knowledge questions were 66.7% (SD: 33.7) and seven questions had a percentage of right answers greater than 70%. On the contrary, three questions were answered correctly by less than one-third of the population. Furthermore, it was noteworthy that only 8.9% of athletes correctly answered question 4 (Figure 2C).

In regard to skin examination and monitoring habits (Table 3), it was found that less than one-third of those surveyed stated they regularly examined their skin and less than 24% had examined their skin in the last 3 months. In addition, 39.7% of those surveyed stated they had never visited a dermatology clinic and only 14.6% had gone in the last year. In regard to their personal medical history, 60 athletes of those surveyed (5.5%) had been previously diagnosed with skin cancer; more specifically, 48 (80%) had been diagnosed with keratinocyte carcinoma and 12 (20%) with melanoma.

3.3 | Evaluation of an intervention in the prevention of skin cancer

3.3.1 | Skin screening exams

All participants (8904 athletes) in this edition of the 101 km de Ronda race were invited to take part in this part of the study carried

TABLE 2 Sociodemographic characteristics of race and survey participants, and sun characteristics, sunburns and sport sun exposure habits findings.

	Total [*n* = 8904]	
Race participants	***n***	**%**
Gender		
Male	8066	90.6
Female	838	9.4
Age		
Mean	46.0	
Category		
Trail running	5609	63.0
MTB	3295	37.0
	Total [*n* = 1145]	
CHACES survey participant	***n***	**%**
Gender		
Male	902	78.8
Female	243	21.2
Age		
Mean – SD	47.1	8.6
Category[(1)]		
Trail running	823	72.0
MTB	320	28.0
Skin color[(2)]		
Very light – light	374	32.7
Medium	486	42.5
Dark	284	24.8
Sun reactive skin type[(3)]		
I (Always burn, never tan)	54	4.8
II (Usually burn, tan less than average, with difficulty)	214	18.8
III (Sometimes mild burn, tan about average)	624	54.9
IV (Rarely burn, tan more than average)	244	21.5
Sunburns in the previous year		
None	481	42.0
1–2	460	40.2
3 or more	204	17.8
Days of sun exposure while doing outdoor sport[(4)]		
<30 days	81	7.1
31–90 days	291	25.5
>90 days	770	67.4
Hours of sun exposure while doing outdoor sport[(5)]		
<=2 h	692	60.6
3 or more hours	450	39.4

Note: Losses: 1 = 2; 2 = 1; 3 = 9; 4 = 3; 5 = 3.

Abbreviations: MTB, Mountain biking included five athletes in the E-Bike category; SD, Standard deviation.

out the day before the race. A total of 170 athletes (1.9%)—mean age of 46.3 years (SD: 10.4), 73.3% were men—voluntarily took part in the intervention (Table S3). As described in methods participation in this part of study included receiving: a dermatologic screening exam with skin cancer risk factors registry, photoprotection and skin self-examination recommendations, and a pamphlet with the main recommendations and samples of sunscreen.

The prevalence of a prior skin cancer diagnosis among participants in the examination was 3% (one case of melanoma and four cases of keratinocyte carcinoma). Among the findings in athletes who were examined (Figure 3), 13 lesions suspected of malignancy were found (7.7%): three melanomas (1.8%), two basal cell carcinomas (1.2%), and eight actinic keratoses (4.7%). By gender, from the 128 men analyzed 6 presented actinic keratosis (4.7%), 3 had lesions suspicious of melanoma (2.3%) and 1 BCC (0.8%) compared to 3 actinic keratosis (7.1%) and 1 BCC (2.4%) found in 42 women analyzed.

Sunburn at the time of the examination were found in 21.9% of men and 11.9% with similar distribution in both genders: face, neck, thorax, and arms, though in men, ears and bald spot were the most common areas of sunburn. In regard to chronic actinic damage, that was found in at least one location in 60.9% of men and 64.3% of women, the face and trunk were found to be the principal locations, followed by the neck. All participants with findings suggestive of malignancy were urged to visit their specialists to continue with the evaluation. Then, each athlete received personalized recommendations on healthy sun exposure, adequate use of photoprotective measures, and skin self-examination methods including ABCDE rule.

3.3.2 | Satisfaction

The satisfaction survey for participants in the skin cancer and photoprotection pilot intervention was completed by 111 athletes (response rate = 62.3%). The results showed that 95.5% evaluated the intervention as excellent, 96.4% would recommend doing it in future editions, and 64.5% would recommend doing it at other sports events.

4 | DISCUSSION

Outdoor physical activity has been shown to improve both the physical capacity and overall well-being of athletes who take part in it.[28] However, elevated UV radiation exposure, such as that received during extreme sports competitions and while training, have been associated with increased risk of skin cancer and other non-skin neoplasms in large cohort studies.[29] In addition, high temperatures and high relative humidity during intense physical activity are associated with episodes of heat stroke or dehydration.[30] This study evaluates the risk of sun exposure, photoprotective and skin monitoring practices, as well as innovative skin cancer prevention interventions in extreme sport challenges.

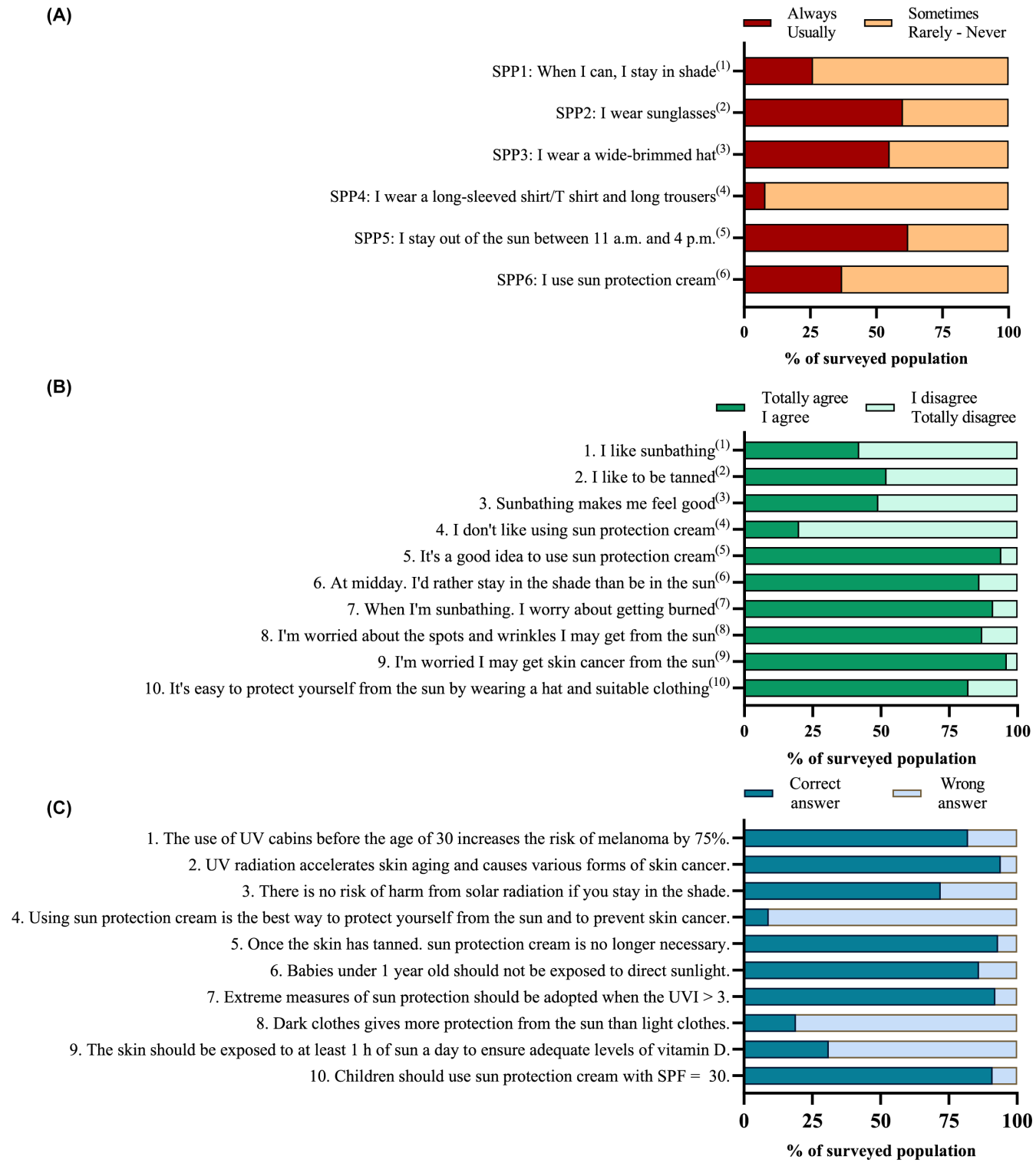

FIGURE 2 Sun-related habits (A), attitudes (B), and knowledge (C) of surveyed athletes. SPP, sun protection practice. Losses: (A): 1 = 42; 2 = 39; 3 = 40; 4 = 41; 5 = 38; 6 = 39. Losses: (B): 1 = 50; 2 = 51; 3 = 49; 4 = 52; 5 = 51; 6 = 50; 7 = 50; 8 = 50; 9 = 49; 10 = 53. (C) Unanswered questions were included as an incorrect response.

The results obtained on the environmental dosimetry showed a high risk of UV radiation exposure during the race, which reached maximum UVI values of greater than 8 during the middle hours of the day and potential radiation values of 6.2 SED/hour between 2:00 PM and 4:00 PM, when all participants were competing in the race. In addition to these environmental data, a mean total effective dose of almost 30 SED was found, much higher than the maximum effective UV dose for unprotected skin recommended by the International Commission on Non-Ionizing -Radiation Protection (ICNIRP) of 1.0–1.3 SED/8 h of exposure.[31] A personal dosimetry

TABLE 3 Skin monitoring habits.

	Total [$n = 1145$]	
	n	%
Do you regularly examine their skin?(1)		
No	728	67.2
Yes	356	32.8
When was the last time you examined your skin?(2)		
Less than 3 months	255	24.0
4–6 months	82	7.7
7–12 months	75	7.0
Older than 12 months	652	61.3
Have you ever visited a dermatologist?(3)		
No	432	39.7
Yes	656	60.3
When was your last visit to the dermatologist?(4)		
Less than 1 years	149	14.6
1–2 years	144	14.1
3–4 years	179	17.5
5 or more years	551	53.9
Have you ever been diagnosed with skin cancer?(5)		
No	1023	94.5
Yes[a]	60	5.5

Note: Losses: 1 = 61; 2 = 81; 3 = 57; 4 = 122; 5 = 62.

[a]BCC ($n = 18$), melanoma ($n = 12$), other skin tumor/not described ($n = 30$).

study conducted in Europe, which also used VioSpor biological dosimeters, analyzed the UV exposure received by athletes in different disciplines. The values recorded by the hikers studied was 8.1 SED with a range of 1.8–19.5 SED over a mean exposure time of 6.4 (4.3–9.5) hours; 7.5 SED with a range of 2.0–13.8 SED and a mean exposure time of 4 h for all tennis players; and 14.6 SED with a range of 9.3–23.8 and a mean exposure time of 18.3 (8.8–22.8) hours for runners.[16] These values, which are lower than those found in our study, may be due to dosimeter placement. They were located on these athletes' backs rather than the helmet or shoulder of participants in this study. The most recent results on triathlon, extreme triathlons (Ironman), and training sessions for them using polysulfone dosimeters reflected values of up to 6.8 SED/hour, similar to those in our study. The total effective dose was between 29.8 and 33.9 SED in Ironmans in different locations in Australia and New Zealand.[32]

High doses of UV radiation received during sports competitions were accompanied by the radiation received during the more than 90 days of outdoor sports practice that more than 60% of those surveyed reported. Sixty percent of those surveyed followed the main photoprotection method recommended by the WHO to reduce UV radiation exposure in the middle hours of the day, but this means that nearly 40% are frequently exposed to very high UVI levels such as those recorded in this race. Although knowledge regarding UV radiation photoprotection was acceptable, with a percentage of correct answers above 65%, and favorable attitudes toward photoprotection were found among our respondents, the photoprotective habits have significant room for improvement. Respondents indicated that forgetting to apply it was the main barrier to implementation. This indicates a lack of integration of healthy photoprotection habits among the athletes surveyed. Other barriers reported, such as the financial cost of sunscreen and an unpleasant sensation while doing sports, may indicate a lack of awareness regarding the skin cancer risk they are exposed to.

On the whole, these results are in line with those of other groups that are especially vulnerable due to their high sun exposure, such as outdoor workers,[33] especially lifeguards,[34] and other athletes who participate in water sports.[27] Among the latter, no greater implementation of photoprotective measures to protect against their increased exposure was observed compared to other, less exposed groups such as healthcare workers[35] or educators.[36] In comparison, athletes surveyed wore sunglasses and a hat more often, but did not use sunscreen or shady areas. These findings corroborated previous studies on trail runners[37] and mountain bikers.[19]

The results of the CHACES questionnaire yielded worrying results given that, in this high-risk population in which more than suffered sunburns in the last year and some had three or more. Moreover, more than 60% did not self-examine their skin in the last year and more than 50% had not had a check-up by a dermatology specialist in the last 5 years.

Therefore, the skin cancer prevention intervention conducted on-site during the race allowed for examining and providing personalized recommendations to more than 170 high-risk athletes, mainly men (>75%), who, as reflected in the skin examination questionnaire, do not frequently monitor changes in their skin. This intervention reached a population with a prevalence of prior skin cancer of 3% (5.5% of all those surveyed) in which lesions suspected of malignancy were found in 8.9% (4.7% actinic keratosis and 3% skin cancer). The rate of lesions suspected of malignancy found, namely melanoma (1.8%), and keratinocyte carcinoma (1.2%), is higher than crude incidence rate among the general population in Spain calculated in a recent meta-analysis. The rates obtained from the analysis of works published between 1989 and 2015 were 38.16 (95% CI, 31.72–39.97) cases of melanoma per 100,000 person-years and 113.05 (95% CI, 89.03–137.08) cases of BCC per 100,000 person-years.[38] Although the lesions found require histological confirmation, the percentage of suspicious lesions is slightly higher to that found in examinations performed in other at-risk groups such as the workers and guests at Costa del Sol hotels (2.2%: six lesions in 278 individuals),[39] but lower than the rate found among workers and players at golf courses (6.7%: 23 lesions in 242 individuals)[40] and outdoor workers (6.3%: eight lesions in 128 individuals, of which five were confirmed via biopsy).[33]

The excellent score obtained on the satisfaction questionnaire conducted among athletes after the intervention, in addition to the benefits of repeating the intervention in future editions and extending it to other sports competitions, supports the positive impact of

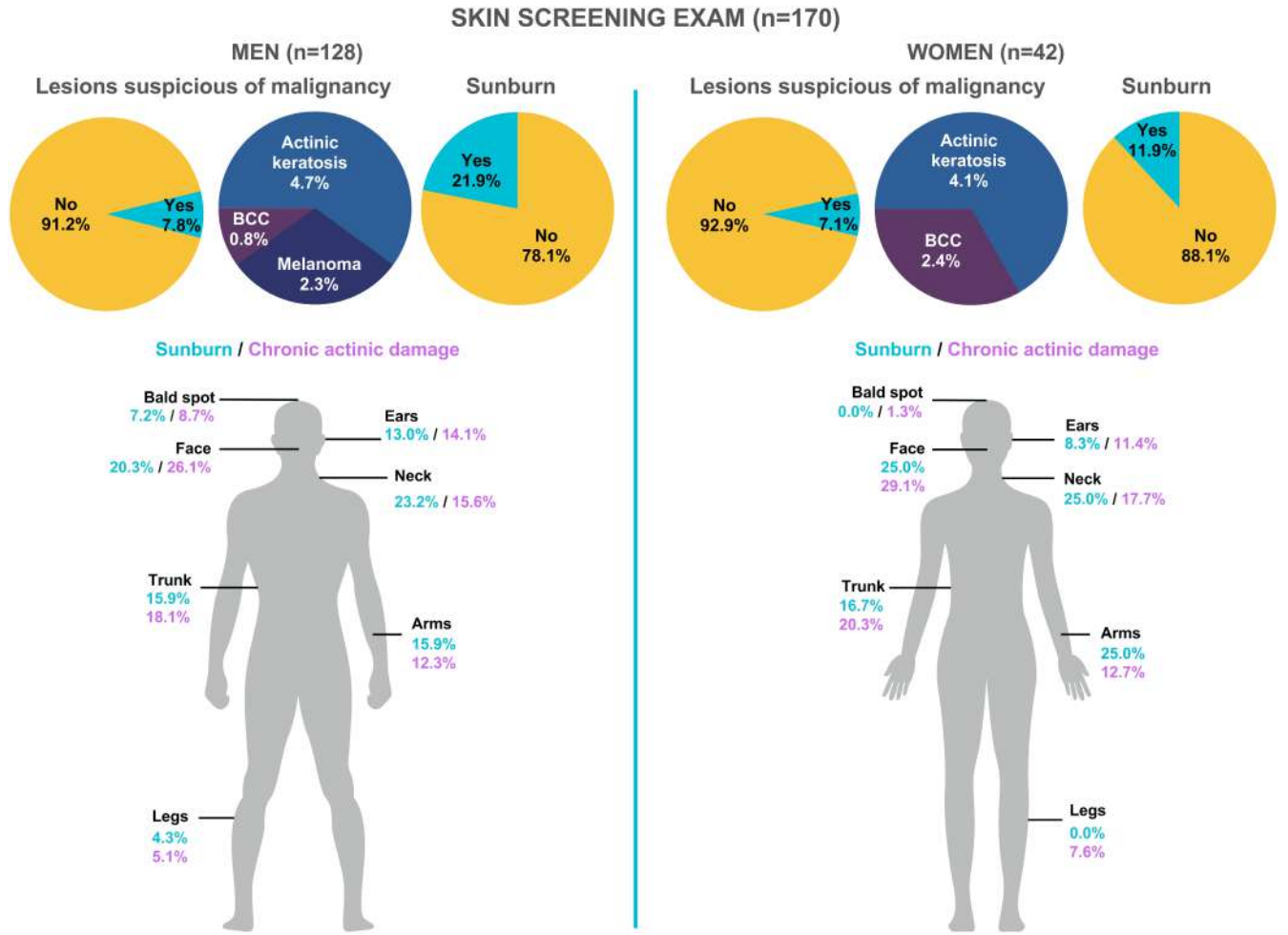

FIGURE 3 Skin screening findings segregation by gender and anatomical location. The presence of lesions suspicious of malignancy (actinic keratosis, melanoma and keratinocyte carcinoma: basal cell carcinoma (BCC) and squamous cell carcinoma (SCC)) and sunburn in any location at the moment screening on each participant is represented in pie charts. Body location of multiple findings of sunburn (100%) and chronic actinic damage (100%) among participating athletes is represented as frequency distribution.

the intervention in terms of its viability, healthcare impact, and impact on society.

The results of this work highlight the need to protect the health of athletes who participate in extreme sports competitions, such as the one analyzed, both by designing safer races with shady routes that are held in months or hours of less UV radiation and by facilitating photoprotective measures to athletes (sunscreen, clothing, and hats with UPF).[15] In addition, interventions in other contexts based on the use of personal dosimeters, UVI measurement devices, or mobile phone Apps (SunSmart App) have been shown to reduce UV radiation exposure[41] and increase sunscreen reapplication[42] among participants. These improvements are highly useful not only in competitions but also in athletes' training sessions. However, these interventions have not been demonstrated to improve photoprotective habits among those who received the intervention,[41] and thus a skin cancer awareness and prevention intervention such as the one conducted could complement the above proposals.

The limitations of this study mainly include geographical and cultural limitations as well as biases arising from the use of self-completed questionnaires (subjectiveness regarding the behaviors referred to, interpretation of questions, memory bias, etc.). However, this study has a large sample size in each of its elements and has been conducted using established, validated tools such as biological dosimeters, the CHACES questionnaire, and an examination conducted by dermatology specialists with clinical diagnostics tools. In addition, it has the novelty of a comprehensive, on-site skin cancer prevention intervention conducted during a race.

In conclusion, this study determined that the *101 de Ronda* race entails extreme photoexposure risk and, in consequence, skin cancer risk. The participants demonstrated deficient skin cancer prevention habits, attitudes, and knowledge. Our multicomponent, on-site intervention model yielded very positive results in regard to detecting potentially malignant lesions and participant satisfaction which, in the future, should be tested in other sports scenarios. It is urgent to implement improvements that protect the health of athletes who do outdoor sports and especially those in long-duration disciplines.

AUTHOR CONTRIBUTIONS

Concept and design: MTM and NBS. Data collection: ARM, CVP, JAA, DDM, MRP, MVGA, LJL, NBS, MTM. Data analyses: ARM, JAA, FRR, JVGM. Interpretation: all authors. Drafting of the manuscript: ARM, FRR, NBS, MTM. Supervision, critical revision and approval of the manuscript: all authors.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

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

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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