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SKIN CANCER RISK IN WATER SPORTS PARTICIPANTS: ULTRAVIOLET RADIATION EXPOSURE AND PHOTOPROTECTIVE BEHAVIORS IN THE CONTEXT OF CHALLENGES AND PREVENTIVE STRATEGIES – A NARRATIVE REVIEW

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ABSTRACT

Background: Water sports create a unique "high-exposure trap," significantly increasing the risk of melanoma (MSC) and non-melanoma skin cancer (NMSC) due to intense ambient UV radiation and surface reflectance.
Objective: To evaluate specific risk factors and analyze the mechanical, physiological, and behavioral barriers to effective photoprotection in maritime environments.
Methods: A narrative review of PubMed, Scopus, and Web of Science (February 2026) focusing on UVR exposure and protective behaviors in aquatic athletes.
Results: Participants face synergistic UVR doses from direct solar radiation and surface albedo (up to 25%). Diagnosis of early damage is often hindered by the cooling effects of water/wind, which mask erythema. Standard photoprotection frequently fails due to sunscreen wash-off, chemical conjunctivitis, and thermoregulatory constraints of clothing. Professional athletes exhibit a higher incidence of field cancerization and a significant "knowledge-behavior gap" compared to recreational users.
Conclusion: Generic guidelines are inadequate for the maritime setting. Specialized protocols are required, including friction-resistant sunscreen formulations and optimized UPF 50+ apparel. Mandatory dermatological screening and targeted education are essential to mitigate oncological morbidity in this high-risk population.

KEYWORDS

Skin Cancer, Melanoma, Water Sports, Ultraviolet Radiation, Photoprotection, Albedo

CITATION

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1. Introduction

Skin cancers, defined as malignant neoplasms originating from epithelial cells, represent the most prevalent group of oncological diseases. Non-melanoma skin cancers (NMSC) predominate, with basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) representing approximately 98% of the total disease burden in this category. The incidence of BCC and SCC exhibits a direct correlation with cumulative ultraviolet radiation (UVR) exposure, while demonstrating an inverse relationship with the degree of cutaneous pigmentation across various populations [1]. Furthermore, the relationship between ultraviolet radiation and the development of melanoma skin cancer (MSC) is both acute and highly complex. Unlike NMSC, which often correlate with cumulative dose, melanoma risk is significantly exacerbated by intermittent, high-intensity sun exposure and a history of blistering sunburns, which serve as a primary drivers of melanomagenesis [2].

Participation in water sports is inherently linked to an elevated risk of cutaneous malignancies. As a strictly outdoor activity, it entails obligatory and prolonged exposure to solar radiation, often exacerbated by high levels of reflected UVR from water surfaces, thereby increasing the cumulative and peak UV dose.

Despite the beneficial effects of sun exposure during water sports, which facilitates the conversion of 7-dehydrocholesterol into vitamin D—a compound essential for intestinal calcium absorption—the cumulative genotoxic effects of UVR promote DNA damage and subsequent oncogenesis [3]. Aquatic activities in comparison to other outdoor activities involve a multifactorial increase in UVR dosage. Participants are subjected to both direct solar irradiation and significant albedo (reflected radiation) from the water's surface. Furthermore, the presence of surface water droplets may exacerbate epidermal damage through a "lens effect," potentially focusing radiation and increasing the risk of acute photodamage [3-4]. Epidemiological data suggest that the elevated incidence of malignant melanoma (MM) among surfers is significantly influenced by indirect UVR exposure via surface reflectance. According to the World Health Organization (2016), while standard surfaces such as grass, soil, and open water reflect approximately 10% of UV radiation, and dry sand reflects 15%, sea foam exhibits a substantially higher reflectance of 25%. This additive UVR flux from the aquatic environment represents a critical environmental cofactor in the pathogenesis of cutaneous malignancies in water-based athletes [5]. Another significant determinant of cutaneous malignancy is the cumulative

duration of photoexposure. Multiple studies indicate a higher prevalence of skin cancer among older and more experienced water sports athletes, demonstrating a strong positive correlation between the total years of athletic training and the cumulative solar UVR dosage [6-7]. Professional athletes constitute a high-risk demographic due to the nature of their competitive schedules. Regattas and tournaments are frequently mandated during midday hours, rendering the avoidance of peak UVR intensity practically impossible. This schedule forces elite athletes to train and compete during the most intense sun hours, making it nearly impossible to avoid dangerous levels of radiation. As a result, they reach the erythemal threshold (the point where the skin starts to burn) much faster than the general population [3].

There are well-established standard photoprotective measures—including sunscreen, protective clothing such as a broad-brimmed hat, sunglasses, and protective clothing (tightly woven fabrics in long-sleeved shirts and long pants), shade-seeking, and routine dermatological surveillance. However, patient compliance remains significantly compromised in the athletic population. The unique physiological and environmental demands of water sport participants impose substantial practical limitations on these interventions, often rendering traditional recommendations ineffective or difficult to implement [4, 7-10].

The aim of this review is to assess the risk of skin cancer among water sports participants and to analyze the challenges related to photoprotective practices. This review examines key risk factors for skin cancer that are difficult to mitigate during water sports participation and discusses the challenges athletes face in preventing excessive ultraviolet exposure.

2. Methodology

Data for this narrative review were obtained from three bibliographic databases: PubMed, Scopus, Web of Science and Academic Platform of Journals (APCZ). The literature search was conducted in February 2026 using the following combination of terms: (“skin cancer” OR “melanoma” OR “non-melanoma skin cancer”) AND (“water sport” OR “surfing” OR “sailing” OR “swimming”). Only studies published in English were included, and no restrictions were applied regarding publication date.

Additionally, the reference lists of relevant articles were screened to identify further eligible studies. Duplicate records were removed prior to screening. Studies were initially assessed based on titles and abstracts, followed by full-text evaluation conducted by the first author.

3. Epidemiological characteristics of skin cancer among individuals participating in water sports

Exposure to ultraviolet radiation (UVR) in aquatic environments carries a synergistic risk of actinic damage. This is attributed to the high albedo of the water surface, which reflects a significant portion of incident UVR, and the compromised efficacy of topical photoprotection. Standard sunscreens often fail upon initial immersion due to mechanical wash-off and rapid emulsification in moving water [11]. Consequently, the cooling effect of water may mask the early symptoms of erythema, leading to prolonged exposure, severe sunburns, and a significantly elevated cumulative risk of cutaneous malignancies. Engagement in water sports necessitates prolonged outdoor activity during peak solar radiation hours, often dictated by optimal wind and thermal conditions. Competitive events, such as regattas, are typically scheduled from morning through mid-afternoon without structured break to avoid peak UV exposure [3]. This mandatory exposure during solar zenith, combined with the inability to seek shade, significantly exacerbates the risk of acute solar erythema and cumulative actinic damage.

According to studies, surfers and swimmers—representing water sports participants—experience sunburn significantly more frequently compared to individuals engaged in other outdoor activities, such as walking or running [5]. For example, most kitesurfers experienced at least one sunburn during the previous sports seasons, and 43.1% reported being sunburned at least three times [4]. Similar statistics have also been reported for swimmers, windsurfers and surfers, who frequently experience sunburn [11-12]. Frequent sunburns in water sports enthusiasts cause direct genetic damage, often manifesting as visible changes in the shape and asymmetry of existing nevi. These repetitive inflammatory episodes significantly increase the risk of malignant transformation, accelerating the progression toward cutaneous malignances. .Excessive sunburns correspond to a higher risk of MM, as reported by Dozier et al. (1997), who identified actinic keratoses (AKs) and BCCs in nearly one-third of surfers included in their study [13]. Both NMSC and MM have also been reported among sailors [14].

While recreational water sports enthusiasts represent a significant risk group for skin malignancies, clinical data indicate that professional athletes report a disproportionately higher incidence of cases [6, 15]. This discrepancy may be attributed to the significantly higher cumulative UV exposure among professionals. Unlike recreational enthusiasts, whose participation is often sporadic and weather-dependent, professional athletes undergo rigorous, year-round training regimens. This results in chronic, daily exposure to high-intensity solar radiation over many years, leading to a profound 'field cancerization' effect and a markedly elevated lifetime risk of cutaneous malignancies. Furthermore, age and cumulative yearslong experience serve as independent risk factors, with a higher prevalence of skin malignancies reported in older athletes compared to their younger professional counterparts [6-7].

Regarding the anatomical distribution, skin malignancies are most frequently localized on the upper body, with a predilection for the head - especially the face—including the cheeks, nose and lips, which exhibit the highest susceptibility to sunburns, followed by the upper extremities [3, 6-7,16]. This distribution pattern correlates with the maximal UV irradiance received by these prominent surfaces during aquatic activities, where the lack of photoprotective coverage is most pronounced.

4. Limitations of Photoprotective Practices in Water Sports Participants

The nature of aquatic environments necessitates more rigorous photoprotection than terrestrial sports. While the application of sunscreens with a Sun Protection Factor (SPF) > 15 is a foundational recommendation [8, 10], its efficacy is severely compromised in water. Mechanical abrasion from waves and equipment, combined with the water solubility of many formulations, leads to rapid depletion of the protective film [11]. This necessitates frequent reapplication, which presents a significant obstacle for athletes. Consequently, patient compliance remains low, as athletes frequently neglect reapplication during active training sessions, apply too thin a layer to the skin, or use sunscreen improperly by covering only specific areas of the body instead of the entire surface [3, 5, 7, 14].

Furthermore, the properties of many sunscreens contribute to physical discomfort and performance inhibition. The sticky texture of many high-SPF products can cause cutaneous irritation in saltwater environments and can even induce conjunctivitis if the product migrates into the eyes during activity [11,13]. Such ocular irritation is not merely a nuisance but a safety risk that can impair the athlete’s visual field and overall performance [9].

Physical barriers, such as clothing, also present distinct limitations in a maritime context. While long-sleeved shirts and long pants provide reliable coverage, they can significantly impair thermoregulation by reducing skin breathability and evaporative cooling, potentially increasing the risk of heat-related illness. Consequently, athletic apparel should be optimized by utilizing UPF 50+ rated fabrics specifically engineered for high UV opacity, combined with light colors to maximize reflectance. Despite these technical advancements, athlete compliance remains low due to perceived thermal discomfort in high-ambient temperatures.

Furthermore, photoprotection of the head and ocular region is critical given the elevated risk of actinic damage. Wide-brimmed hats or caps providing neck coverage are recommended, while polarized sunglasses are essential to mitigate ultraviolet radiation and glare. However, for certain water sports, such as surfing, the use of hats or sunglasses is often functionally impossible due to high-velocity water impact and the risk of loss during maneuvers. This leaves the head and neck—areas of high cumulative UV exposure—vulnerable to actinic damage and subsequent skin cancers [7].

The strategy of seeking shade becomes largely ineffective in open-water sports, which are typically practiced around midday, when solar radiation is at its peak and natural shade is virtually unavailable [3].

Furthermore, the cooling effect of the wind and water may mask the heat of direct solar irradiation, leading to a diminished perception of thermal strain and a subsequent delay in photoprotective behaviors. In the absence of natural canopies or structural barriers, the maritime environment creates a "high-exposure trap," where the athlete is subjected to both direct and reflected UVR, significantly increasing the risk of acute erythema and long-term actinic carcinogenesis.

Studies suggest that the obstacles to effective sun protection behaviours are further confounded by gender-specific behavioral patterns. Female participants generally demonstrate a higher frequency of overall photoprotective practices, showing a clinical preference for the application of topical sunscreens. Conversely, male participants tend to favor physical barriers, specifically headwear, despite the functional limitations of hats in high-impact water environments. These behaviours may result from lower awareness of the risks and consequences of skin damage among men [17].

This bifurcation in strategy suggests that educational interventions must be tailored to address these specific preferences. For the female cohort, the focus should reside on mitigating the mechanical failure and ocular irritation associated with topical filters. For the male cohort, the clinical challenge lies in addressing the intermittent use of physical barriers and the high incidence of UV-induced pathology in anatomically exposed areas that hats may fail to protect during active maneuvers.

5. Discussion

Research consistently indicates a significant knowledge-behavior gap among elite water athletes. Despite high levels of awareness regarding skin cancer risks, adherence to photoprotective measures remains suboptimal [8-9, 11, 18-26]. This resistance is multifactorial, rooted in long-standing habits, perceived lack of immediate consequences, and substantial thermoregulatory discomfort. In high-intensity maritime sports, physical barriers like hats or sunglasses are often discarded due to compromised aerodynamics or the high probability of equipment loss during maneuvers.

Furthermore, even when protective measures are employed, the maritime environment presents a unique challenge: surface albedo. Water reflects approximately 10-25% of UV radiation, creating an "upward irradiation" effect that bypasses traditional brims and peaks, leading to significant actinic damage on the lower face and chin—areas typically shaded in terrestrial environments.

Topical sunscreens face similar functional hurdles. Constant water contact and perspiration lead to rapid mechanical removal of filters, necessitating a frequency of reapplication that is often logistically impossible during competition or extended training sessions. Additionally, the migration of sunscreen into the periocular region—facilitated by water and sweat—causes chemical irritation (stinging), which directly impairs visual acuity and athletic performance.

The findings of this review highlight a significant pathophysiological paradox in maritime sports: while physical activity is generally protective against systemic malignancies, the unique environmental constraints of the open water create a high-risk niche for cutaneous carcinogenesis. The synergy between high ambient UVR, surface albedo, and exercise-induced immunosuppression necessitates a shift from general public health advice to sport-specific photoprotective protocols. Future interventions should focus on the development of 'friction-resistant' and 'sting-free' sunscreen formulations and the standardization of UPF-rated competition gear, acknowledging that for elite water athletes, traditional measures like 'seeking shade' are functionally obsolete.

Despite the well-documented risks, there is a notable paucity of evidence-based studies evaluating practical solutions to the technical failures of sunscreen application in high-velocity aquatic environments. Furthermore, current literature lacks standardized protocols on optimizing the balance between UV-protective clothing and thermoregulatory efficiency in water sports participants. Therefore, further prospective clinical research is imperative to develop specialized photoprotective guidelines that address the mechanical and physiological constraints unique to the maritime setting.

Given the aforementioned constraints, the primary clinical objective in mitigating skin cancer risk among aquatic athletes should shift toward alternative solutions where standard protocols fail. From a public health perspective, it is more efficacious to promote a reduced but consistent regimen of photoprotection than to risk total non-adherence due to overly burdensome requirements. Acknowledging these limitations allows for the implementation of sustainable, albeit partial, protective behaviors that remain superior to the total absence of UV mitigation.

In conclusion, the multifaceted obstacles to effective photoprotection in aquatic environments—ranging from mechanical product failure to thermoregulatory constraints—necessitate a robust shift in athlete management. Sun-safety education is the cornerstone of this shift, serving as the primary catalyst for modifying high-risk behavioral patterns and improving adherence to sport-specific protection protocols.

Furthermore, given the inherent limitations and high failure rates of primary prevention in water sports, regular dermatological screening programs must be integrated into the standard health maintenance routines of these participants. Skin examinations allow for the early detection of actinic keratoses and early-stage cutaneous malignancies, thereby reducing long-term morbidity. By combining targeted educational interventions with proactive clinical surveillance, we can bridge the current gap in photoprotective efficacy and ensure the dermatological longevity of water sport athletes.

6. Conclusions

This review demonstrates that water sports participants constitute a unique high-risk demographic for both MSCs and NMSCs. The aquatic environment creates a "high-exposure trap" where athletes are subjected to a synergistic UVR dosage—combining direct solar zenith radiation with significant surface albedo, which reflects up to 25% of UV rays. This exposure is further intensified by the "lens effect" of water droplets and the cooling sensation of wind and water, which often masks early erythemal symptoms, leading to prolonged and dangerous levels of photoexposure.

Standard photoprotective measures—such as topical sunscreens, hats, and sunglasses—frequently fail in maritime settings due to mechanical wash-off, ocular irritation, thermoregulatory discomfort, and equipment loss during high-velocity maneuvers.

Consequently, there is an urgent need to shift from generic public health advice to sport-specific dermatological protocols. Future preventive strategies should prioritize the development of "sting-free," friction-resistant sunscreens and specialized UPF 50+ apparel that balances UV opacity with thermoregulatory efficiency. Ultimately, given the technical failure rates of primary prevention in the water, regular dermatological screening must be integrated into the standard health maintenance of aquatic athletes. By combining targeted education that addresses gender-specific behavioral patterns with proactive clinical surveillance for actinic keratosis and early-stage malignancies, we can significantly reduce the long-term oncological morbidity in this high-risk population.

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AI. In the preparation of this manuscript, artificial intelligence tools were used for two primary purposes: to assist in the linguistic refinement of the text, including grammar correction, clarity, and adherence to academic English standards, and to support the analysis of clinical reasoning narratives by identifying potential linguistic patterns associated with logical fallacies.

All AI tools were used only as assistive instruments under direct human supervision. The authors critically reviewed and edited all AI-generated suggestions. The final interpretation of results, classification of errors, and all scientific conclusions were made solely by the authors, who take full responsibility for the content of this publication. AI was used to enhance efficiency in language editing and data processing, and did not replace human judgment at any stage of the research process.

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