Dermatol Ther (Heidelb) (2023) 13:1935–1958
https://doi.org/10.1007/s13555-023-00982-4

REVIEW

Reinforcing Photoprotection for Skin of Color: A Narrative Review

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Received: May 9, 2023 / Accepted: July 11, 2023 / Published online: July 26, 2023

ABSTRACT

Skin of color (SOC) is characterized by increased tendency for tanning and decreased likelihood of sunburns due to the attenuation of sunlight by epidermal melanin. Although this contributes to the decreased incidence of skin cancer among SOC populations, individuals with SOC remain susceptible to various health consequences associated with sun exposure, including non-melanoma skin cancer, photoaging, pigmentary disorders, and photodermatoses — many of which not only present differently, but also disproportionately affect SOC. Prior epidemiological studies have found lower prevalence of sun protection behaviors among individuals with SOC, particularly in sunscreen use, signifying an unmet area for improvement in the prevention of sun-induced dermatologic conditions in these populations. The objective of this narrative review was to summarize the biology and health consequences of sun exposure in SOC, as well as cognitive and behavioral factors that affect the practice of photoprotection behaviors in SOC populations. We also review prior interventions that have been used to enhance photoprotection knowledge and behaviors among individuals with SOC, either in racially and ethnically diverse communities or within specific SOC populations.

Keywords: Skin of color; Photoprotection; Skin cancer; Photoaging; Pigmentary disorder; Photodermatoses; Perception; Knowledge; Intervention; Education

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Key Points
There has been increased recognition of the importance of photoprotection against ultraviolet, visible, and near-infrared radiation in individuals with skin of color (SOC).
Prior epidemiologic studies have shown lower rates of sun protection in SOC populations, particularly in sunscreen use.
Common facilitators of photoprotection behaviors in SOC populations include the prevention of tanning, photoaging, and pigmentary disorders.
Common barriers to the practice of photoprotection behaviors in SOC populations include low perceived risk of skin cancer, aversion to sunscreen, and low access to dermatologic care and counseling on photoprotection.
Various interventional studies in the school, community, and clinic settings have demonstrated success in reinforcing sun protection knowledge and behaviors in individuals with SOC.

INTRODUCTION

Solar radiation that reaches the surface of earth is composed primarily of ultraviolet (UV), visible, and infrared light. Exposure to sunlight may cause short-term responses like sunburns and pigmentary changes, as well as long-term effects like photocarcinogenesis and photoaging. Although the importance of sun protection for preventing melanoma, non-melanoma skin cancers, and photoaging is well-established in fair-skinned populations, the extent to which these recommendations apply for dark-skinned individuals is less clear, especially among members of the public. Guided by recent insights on the interactions of UV, visible, and near-infrared (NIR) radiation with pigmented skin, there has been increased attention towards the importance of photoprotection behaviors in people with skin of color (SOC) [1–5]. With increased knowledge on the effects of sun exposure in individuals with SOC, it is important to recognize barriers to photoprotection in these populations in order to facilitate health behavior change. In this narrative review, we briefly examine the biology and health consequences of sun exposure in SOC. We summarize prior studies on cognitive and behavioral factors that influence photoprotection behaviors across individuals of varying skin types and cultures. Finally, we survey previous public health and individual-based interventions that have been used to encourage photoprotection for SOC.

METHODS

Research articles described in this review were identified with a literature search using Google Scholar, Web of Science, and PubMed. Combinations of the following keywords and phrases were used in search queries: skin of color, skin type, race, ethnicity, sun protection, photoprotection, ultraviolet, visible light, near-infrared, sunburn, tanning, skin cancer, photocarcinogenesis, melanoma, squamous cell carcinoma, basal cell carcinoma, photoaging, pigmentary disorder, melasma, post-inflammatory hyperpigmentation, photodermatoses, sunscreen, sun avoidance, shade seeking, sun protective clothing, attitude, perception, knowledge, culture, public health, intervention, education, counseling, program, application, SunSmart, Hispanic, Asian, African, Black. Additional articles were identified by forward and backward citation search. Articles were reviewed and selected for inclusion based on their relevance. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Biology and Health Consequences of Sun Exposure in Skin of Color

Visually observable skin pigmentation arises from the reflection of incident light by

chromophores within the skin, such as melanin, oxyhemoglobin, deoxyhemoglobin, beta-carotene, and bilirubin [6]. Among these constituents, melanin is the most important in explaining variances in skin tone across skin types, often categorized with the Fitzpatrick skin type (FST) in clinical practice that ranges from I (pale white) to VI (dark brown or black). Darker skin contains higher concentrations of melanin and melanosomes but the same number of melanocytes [7].

Although FST IV to VI are regarded as SOC in most contexts, racial and ethnic groups commonly associated with SOC may exhibit significant heterogeneity in skin tone extending beyond this range. For example, whereas FST generally ranges from IV to VI in Black individuals, FST may range from II to V in Asian individuals and from I to V in Hispanic individuals [8, 9]. Colorimetry and spectrophotometry allow quantification of skin pigmentation [10, 11], but they are less frequently reported in research studies compared with clinician-assessed FST and self-reported race and ethnicity; they are also rarely used in clinical practice. To allow the discussion of SOC in the most inclusive manner and incorporate research studies that only describe participants' race and ethnicity, we broadly define individuals who are not Non-Hispanic White as having SOC, including, but not limited to, those who self-identify with Hispanic ethnicity or Black/African, Asian, Native American, or Pacific Islander race [12].

Higher FST is associated with greater tendency to tan and lower likelihood of developing sunburns with sun exposure, and vice versa. Compared with epidermis from White individuals, epidermis from Black individuals reduces UV-B transmission to the dermis by nearly 75% and UV-A transmission to the dermis by nearly 70% [13]. In terms of sun protection factor (SPF) against UV-B, black epidermis has an estimated SPF of 13.4, whereas white epidermis has an estimated SPF of 3.4 [13]. Increased skin pigmentation is associated with a higher dose of UV light necessary to induce erythema, sunburn cells, and DNA damage [7, 14]. At the molecular level, increased melanin content in pigmented skin attenuates downstream effects of UV exposure such as the generation of cyclobutene pyrimidine dimers, pyrimidine-pyrimidone (6–4) photoproducts, and reactive oxygen species (ROS) that contribute to photocarcinogenesis [14, 15], as well as the induction of dermal collagen breakdown by matrix metalloproteinases that underlies solar elastosis in photoaging [16].

In addition to UV irradiation, visible light, which constitutes 50% of incident solar radiation and independently contributes to ROS formation, can also have an appreciable impact in SOC as this group is particularly susceptible to the pigment-inducing effects of visible light [17, 18]. Whereas the increased melanin in SOC is protective against ultraviolet exposure, there is data to suggest that melanin is a potential mediator of the pigmentation effects associated with visible light [19]. Mahmoud et al. found that visible light induced more pronounced and persistent hyperpigmentation than long-wavelength UV-A light in SOC, with no change in pigmentation observed in light skin [20]. Similarly, Kim et al. showed that repeated visible light irradiation caused immediate pigment darkening and delayed tanning in dark-skinned but not light-skinned individuals [21]. Increased recognition of the pigmentation effects of UV-A and visible light in SOC has led to recommendations that place additional emphasis on protection against these wavelengths in SOC populations [22]. Beyond the visible light spectrum, NIR radiation is also known to disrupt mitochondrial electron transport to induce ROS production and collagen degradation [23]. In contrast to UV-induced free radical production, NIR-induced free radical production has been found to occur to a greater extent in dark skin compared with light skin [24, 25].

Skin Malignancies

Pigmented skin protects against the development of melanoma, as well as non-melanoma skin cancers like squamous cell carcinoma (SCC) and basal cell carcinoma (BCC). Whereas fair-skinned individuals tend to develop melanoma in sun-exposed areas, darker-skinned individuals mostly develop melanoma in non-sun-exposed regions, particularly the palms and soles (i.e., acral lentiginous melanoma) [26–28].

Consistent with this, a systematic review of 13 epidemiologic studies by Lopes et al. did not find an overall link between UV exposure and melanoma in individuals with SOC, though the authors noted that the studies were of moderate to low quality [29]. SCC tends to occur in non-sun-exposed areas in Black and Hispanic individuals, with chronic scarring, inflammatory skin conditions, and immunosuppression being stronger risk factors [30]. In contrast, multiple studies have suggested that SCC is associated with sun exposure in East and Southeast Asian individuals [31–34]. Unlike melanoma and SCC, BCC is associated with UV exposure and occurs predominantly on the head and neck, regardless of skin type [30, 33, 35]. These findings may reflect the differential mechanisms by which sun exposure contributes to the development of melanoma and non-melanoma skin cancer, with the former thought to arise predominantly from intermittent intense sun exposure leading to sunburns (less common in SOC), rather than cumulative sun exposure [36].

Photoaging

Whereas wrinkles and pigmentary changes occur with sun exposure across all skin types, the morphology and timing of these changes often differ. Due to attenuation of UV light by epidermal melanin, individuals with SOC tend to develop signs of photoaging at older ages [37–41]. Photoaging manifests primarily as dyschromia, deep rhytides, and dermatosis papulosa nigra in Black individuals, whereas Asian individuals tend to develop pigmentary changes like solar lentigines before the formation of wrinkles with chronic sun exposure [40, 42]. To account for the unique manifestations of photoaging by skin type, photonumeric scales have been developed specifically for Caucasians [43, 44], Asians [45], and African Americans [46]. Photoaging in Hispanic individuals tends to present as fine wrinkles and cutaneous hyperpigmentation with rete ridge effacement and thin collagen fiber degradation, but the identification of unique features has been difficult owing to the wide heterogeneity of skin tones in this population [40, 42, 47, 48]. However, a study by Hillebrand et al. observed that Hispanic individuals tend to have fewer wrinkles than Caucasian individuals and more wrinkles than African American and Asian individuals living in the same city [49]. The pigmentary condition melasma has also been described as a manifestation of photoaging and is common across various SOC populations [50], as further discussed in the next section.

Photodamaged skin may be treated with topical retinoids, chemical peels, botulinum toxin, fillers, and laser resurfacing, but the tendency for SOC to develop post-inflammatory hyperpigmentation (PIH) makes ablative lasers and deep chemical peels less practical [51]. Considering the chronicity of photoaging, difficulty in reversing its effects, and association with psychosocial burden, early education and practice of sun protection should be emphasized. Besides conventional strategies that that emphasize UV protection, findings on the role of visible and NIR light in inducing ROS and collagen destruction in photoaging has led to recommendations to use tinted sunscreens to protect against visible light, as well as the addition of antioxidant ingredients to attenuate free radical-mediated photodamage [5, 18, 52].

Pigmentary Disorders and Photodermatoses

One of the major health consequences of sun exposure unique to SOC is the development or worsening of pigmentation disorders, including PIH and melasma, which are among the most common dermatologic diagnoses in Hispanic, Asian, and African patients [53–57]. PIH presents as hyperpigmentation at sites of skin irritation, inflammation, and injury and is commonly seen as sequela of acne, eczema, skin trauma, and dermatologic procedures in SOC [51]. PIH is worsened by sun exposure and may require months to years to resolve even after addressing the underlying etiology [51]. With a similarly chronic and refractory time course, melasma manifests as irregular hyperpigmented macules and patches most commonly across the face. Despite the conventional association of melasma with pregnancy, recent studies have reinforced its categorization as a disorder of photoaging [50]. Epidemiological studies have shown high prevalence of melasma in SOC. For example, the estimated prevalence of melasma ranges from 15 to 25% in Indian men, whereas a

study in a Brazilian university found that 34% of female workers had melasma [54, 58]. Both PIH and melasma may be treated with topical agents such as hydroquinone, retinoids, topical steroids, kojic acid, and azelaic acid; chemical peels and lasers are also used but require caution in SOC to prevent further induction of PIH, which is a major challenge when treating pigmentary disorders in SOC [51, 59]. Besides pigmentary disorders, SOC populations are also disproportionately affected by photodermatoses like polymorphous light eruption, chronic actinic dermatitis, systemic lupus erythematous, and lichen planus that are exacerbated by sun exposure and would benefit from photoprotection [60].

Facilitators and Barriers to Photoprotection Behaviors in SOC Populations

Facilitators

The practice of photoprotection behaviors such as seeking shade, wearing sun protective clothing, and applying sunscreen has been recommended for individuals of all skin types [2, 3, 22]. However, prior epidemiologic studies have shown lower rates of sun protection behaviors among individuals with SOC, especially in sunscreen use [61–66]. Qualitative and survey-based studies have provided insight towards facilitators and barriers to the practice of sun protection among SOC populations. The most common reasons for practicing sun protection across SOC populations include the prevention of tanning, photoaging, and pigmentary disorders like melasma [67–74]. In a survey of Asian/Pacific Islander and Hispanic individuals in Southern California, protection against sunburn and skin cancer were both noted as facilitators for sunscreen use, with the former reason more frequently endorsed by participants [67]. Despite the avoidance of tanning being a strong incentive for sun protection across SOC populations, multiple studies have stressed the dependence of tanning beliefs on cultural environments [75–82]. For example, the traditional preference for lighter skin in women exists in many East Asian cultures and remains common in commercials for cosmetic products [79]. Similarly, the practice of sun avoidance out of aesthetic preference for lighter skin has also been described in surveys of African American college students [81].

Barriers

Acculturation to European and American societies has been associated with increased sun exposure and desire for tanning among Asian and Hispanic populations [75–78, 80, 82]; while this may reflect a shift in aesthetic ideals, the desire to conform to social norms may also play a separate role in the increased practice of outdoor activities and tanning [79]. Social norms may also affect the acceptability of sun protection methods such as the use of parasols, which is uncommon in the United States but practiced in many regions of the world [79, 83]. Additional barriers to practicing photoprotection behaviors in SOC populations have been described, including low awareness and perceived risk of developing skin cancer [66, 69, 70, 84]. Whereas the greasy, laborious, and costly nature of sunscreens have been noted as barriers to sunscreen use in studies involving SOC populations [67–69, 73, 85], these reasons are likely not specific to SOC. However, the thick white residue left by many physical sunscreen formulations poses a unique challenge for individuals with SOC and may prevent the sufficient application of sunscreen to recommended amounts [86]. While tinted sunscreens that mimic darker skin tones present a cosmetically acceptable solution [52], prior studies have found lower rates of physician counseling on sunscreen use in patients with SOC, as well as low emphasis on the cosmetic elegance and feel of sunscreen in recommendations [87, 88]. Insufficient conversations on sun protection may also result from low access to dermatologic care and skin cancer screening in general across SOC populations [89–91]. Though not unique to SOC populations, concern for and adherence to masculine norms have been associated with decreased sunscreen use across male individuals of diverse races and skin types [63, 92–94].

Interventions to Encourage Photoprotection for SOC

Community-Level Interventions

To address the health consequences of sun exposure, various public health interventions have been examined in racially and ethnically diverse settings and within specific SOC populations. The SunSmart program in Australia is among the most well-established public health efforts to promote sun protection behaviors such as using hats, sunglasses, sunscreen, and sun-protective clothing, and an analysis of data from 1987 to 2017 across 13,285 individuals revealed increased sun protection behaviors after adjusting for skin sensitivity that coincided with recent decreases in the incidence of melanoma in Australia [95]. Similar programs have been studied in other regions and contexts, particularly in the school and classroom setting. The Sun Protection of Florida's Children project, which provided educational sessions and free wide-brimmed hats to a racially diverse cohort of 4th grade students (around 50–60% non-White), observed increased use of hats in school, although little change in the use of hats was observed outside of school [96]. Another randomized controlled trial (RCT) of the Sunny Days, Healthy Ways (SDHW) curriculum across Colorado, New Mexico, and Arizona found increased sun protection knowledge, self-efficacy, and behaviors, as well as decreased preference for tanning and perceived barriers to sunscreen use across middle school students who received six 50-min educational sessions on sun safety and protection; around 20% of participants in this study were of Black/African American, American Indian/Alaska Native, or Asian race, and around 25% were of Hispanic ethnicity [97]. The SDHW curriculum was subsequently adapted by Miller et al. in a series of studies involving Hispanic elementary school students in Los Angeles, California. One observational study found improvements in sun protection-related knowledge, attitudes, and self-efficacy among students after three 1-h sessions of lectures and interactive activities [98], whereas a subsequent RCT observed increased shade seeking and use of sun-protective clothing among students who received the intervention [99]. In Beijing, China, an RCT by Lai et al. involving high school students similarly found improvements in sun protection knowledge, shade seeking, and sun avoidance during peak hours following either 1-year or 2-year sun safety educational programs [100].

Incorporation of Multimodal and Collaborative Components

Several studies have employed interventions beyond education alone to encourage sun protection, as well as methods that require active input from participants. Cheng et al. performed an RCT in Beijing, China that revealed greater improvement in sun protection knowledge and behavior among Olympic Games volunteers who received a multicomponent intervention consisting of educational sessions, free sunscreen, and written materials, compared with those who received written materials alone [101]. Glanz et al. used a combination of activities, booklets, scoreboards, gift rewards, and free sunscreen to enhance sun protection knowledge and habits among 6- to 8-year-old children, their parents, and staff in an observational study across recreation centers in Hawaii; most parents and their children in this study were White or Asian/Pacific Islanders, whereas the majority of staff members identified as Hawaiian, Asian/Pacific Islander, or mixed ethnicity [102]. Another study in Hawaii by Cassel et al. investigated a school-based skin cancer prevention program in a predominantly Asian or Hawaiian sample of 10th grade students, using presentations, educational brochures, UV radiation-sensitive wristbands, message pens with reminders, and talks by local athletes to enhance sun protection knowledge [85]. While limited improvements were seen in attitudes on tanning, this study was unique its use of discussions with the target audience (10th grade students) to develop and revise the intervention [85]. Similarly, Huh et al. held discussions with children and parents from predominantly Hispanic local communities in California to co-design a mobile SunSmart application that incorporated games, location sensing, and real-time adaptive reminders [103]. Zhou et al.'s interventional trial on college students in Longyan, China fostered the intention to use

sunscreen among participants by having them devise individualized action plans for using sunscreen and coping plans to address anticipated barriers [104]. The benefit of participant-centered approaches was also shown in Duponte et al.'s study in Sao Paulo, Brazil, which incorporated the "teach back" method to enhance understanding and improve sunscreen use among 8th grade students [105].

Appearance-Based Versus Health-Based Messaging

Efforts to promote sun protection often involve depictions of the consequences of sun exposure, which necessitates balancing between aesthetic-based and disease-based messages. In an RCT in San Diego, California involving 133 undergraduate students of mostly Caucasian (45%), Asian (35.3%), or Hispanic (11.3%) race and ethnicity, Mahler et al. found that the provision of education on photoaging and UV facial photographs (highlighting uneven pigmentation from sun exposure) led to increased sun protection intention and decreased skin darkening at follow-up [106]. Tuong et al. showed that educational videos focused on photoaging promoted sunscreen adherence more than those focused on skin cancer in an RCT in North California that involved 50 high school students (around 90% non-White), although both photoaging- and skin cancer-based methods led to improved knowledge on sunscreen and UV exposure [107]. The respective strengths of photoaging- and skin cancer-based messaging were shown by Hernandez et al.'s observational study involving 80 Hispanic adults in West Chicago, in which women reported more interest in preventing photoaging than men, but more than 90% of participants found educational videos on skin cancer prevention more persuasive [74]. Given these findings, the authors suggest the use of information on photoaging to draw initial attention, especially among female individuals, followed by the establishment of further motivation with skin cancer-related messages [74]. The strong behavioral impact of photoaging-based interventions on sunscreen use and avoidance of tanning was also shown in a series of trials by Brinker et al. in Brazil, in which secondary school students participated in classroom sessions that used a mobile application to simulate the effects of long-term UV exposure on photographs of their own face [108, 109]. Importantly, the authors found similar effectiveness and reception of this intervention among students with FST I–II and those with FST III–VI [108].

Individual Education and Counseling

Several studies have examined the role of individual counseling and education on promoting sun protection. A systematic review of 21 trials published by the United States Preventative Services Task Force (USPSTF) in 2018 suggested that behavioral interventions may encourage sun protection behavior, but their long-term effects on the incidence of sunburn and skin cancer remain inconclusive [110]. As few studies to date have focused on individuals with SOC, the USPSTF currently recommends behavioral counseling on sun protection for fair-skinned individuals only and notes the need for further research in SOC populations [111]. Nevertheless, studies have shown how education and counseling may improve sun protection knowledge and behavior in SOC individuals. In a study involving 40 African American, 40 Hispanic, and 40 Asian participants in Chicago, Robinson et al. found that focus group discussions on educational material from the American Cancer Society were sufficient to improve participants' understanding on the risks of sunburn and skin cancer in darker skin types [70]. Chao et al. found that educational pamphlets provided in the clinical setting, either with or without emphasis on SOC, improved understanding on the link between sun exposure and melanoma in a sample of predominantly African American patients [112]. Similarly, Tsai et al. observed improvements in self-reported sun protection knowledge, self-efficacy, and behaviors in African American individuals who received brochures and video tutorials at an outpatient dermatology clinic [113]. Clinic-based counseling has also shown effectiveness in promoting photoprotection behaviors in pediatric patients. In an RCT by Ho et al. involving 300 pairs of caregivers and children aged 2–6 years old, among which

26.1% were of Hispanic ethnicity, 13.1% were Black, and 12.4% were Asian/Pacific Islanders in the intervention arm, the provision of read-along books on sun protection, swim shirts, and weekly text-message by pediatric clinics led to increased sun protection behaviors and reduced skin tanning [114]. The stages of change framework (i.e., precontemplation, contemplation, preparation, action, and maintenance) is often used in the clinical setting to encourage health behavior changes, such as smoking cessation and weight loss, and Norman et al. found similar success in using this approach to encourage sun avoidance and sunscreen use in a sample of 800 adolescents (around 40% non-White) in the primary care setting [115].

CONCLUSIONS

In this narrative review, we discussed the unique health consequences of sun exposure, cognitive and behavioral factors that affect photoprotection behaviors (Table 1), as well as interventions that have been investigated to promote photoprotection for SOC (Table 2). While these findings are not exhaustive or representative of all SOC populations, they illustrate considerations that may guide recommendations on photoprotection for SOC in various settings (e.g., community, school, clinic). From a behavioral standpoint, individuals with SOC experience less reinforcement to practice photoprotection behaviors due to decreased incidence of sunburn and skin cancer as well as delayed onset of photoaging compared with fair-skinned individuals. Low awareness on the unique pigmentation effects of UV and visible light in SOC, among both patients and health professionals, may also contribute to underutilization of photoprotection as prevention against pigmentation disorders in SOC. For this reason, it is essential to increase patient awareness on the avoidable health consequences of sun exposure specific to their skin type. Among potential consequences of sun exposure in SOC (e.g., tanning, non-melanoma skin cancer, photoaging, pigmentary disorders), clinicians may emphasize those that are most relevant to patients' personal priorities to encourage the initiation of regular photoprotection, while simultaneously uncovering and addressing additional gaps in knowledge.

We support prior recommendations on the importance of sun protection for SOC, using methods such as sun avoidance, shade seeking, sunglasses, parasols, sun-protective clothing, and broad-spectrum sunscreen covering UV-B, UV-A, and visible light [2, 3, 22]. Given the differential susceptibilities of fair versus pigmented skin to the effects of UV-A, UV-B, and visible light, a "one-size fits all" approach to photoprotection may undermine its perceived applicability when recommended to racially and ethnically diverse populations. Besides establishing guidelines tailored to individual skin types, further research is also needed to optimize the targeted dissemination of these recommendations in the school, community, and clinic settings.

Areas requiring further study in this topic include the magnitude of clinical benefit associated with photoprotection against radiation beyond the UV range, including visible and NIR radiation, as well as the health and economic impacts of public health interventions that promote photoprotection for SOC. Given the ubiquitous nature of visible light and NIR light in both outdoor and indoor settings, recommendations on protection against these types of

Table 1 Common facilitators and barriers to photoprotection reported by individuals with SOC

Facilitators	Barriers
Prevention of tanning	Low perceived risk of skin cancer
Prevention of photoaging	Impracticality of sunscreen (white residue, greasiness, laboriousness, cost)
Prevention of pigmentary disorders	Low access to dermatologic care and counseling on photoprotection

Table 2 Examples of interventional studies that involve the promotion of sun protection knowledge or behavior in SOC individuals

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Hunter et al. (2010) [96]	USA (Florida)	School	RCT	2491 4th grade students from 22 schools Intervention group (11 schools): 49.9% Non-White Control group (11 schools): 60.4% Non-White	Educational classroom sessions Free wide-brimmed hats	Increased proportion of students using hat in school in intervention group No change in use of hats outside of school No change in spectrometer-measured skin pigmentation
Buller et al. (2006) [97]	USA (Colorado, New Mexico, and Arizona)	School	RCT	2038 grade 6–8 children from 30 middle schools Intervention group: Race, 78.6% White, 6.5% Black/ African American, 6.8% American Indian/Alaska Native, 5.0% Asian, 3.1% Native Hawaiian/Other Pacific Islander; Ethnicity, 24.2% Hispanic, 75.8% Non-Hispanic Control group: Race, 77.2% White, 6.3% Black/African American, 8.4% American Indian/Alaska Native, 5.3% Asian, 2.8% Native Hawaiian/ Other Pacific Islander; Ethnicity, 25.7% Hispanic, 74.3% Non-Hispanic	Six 50-min sessions on sun safety and sun protection	Increased sun protection (long-sleeved shirts, sunscreen), knowledge, and self-efficacy Decreased perceived barriers to using sunscreen and preference for tanned skin

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/skin type (if reported)	Interventions	Selected findings
Miller et al. (2015) [98]	USA (Los Angeles, California)	School	Observational	19 elementary schools 777 Hispanic/Latino students Skin tone, 23% fair/medium white, 67% olive/light brown, 8% dark brown/black	Three 1-h lessons over 3 weeks with lectures, indoor project-based activities, outdoor interactive activities	Improved sun protection knowledge, attitudes, and self-efficacy No change in sun protection behaviors
Miller et al. (2021) [99]	USA (Los Angeles, California)	School	RCT	3710 grade 4–5 students in 24 public schools Intervention group (n = 3368): 68.1% Hispanic, 4.6% Non-Hispanic White, 4.1% Asian/Pacific Islander, 8.1% Black/African American, 1.8% American Indian/Native American, 5.4% Mixed Intervention group (n = 342): 80.7% Hispanic, 4.1% Non-Hispanic White, 1.5% Asian/Pacific Islander, 1.5% Black/African American, 2.1% American Indian/Native American, 3.5% Mixed	Sun protection curriculum ± UV science lab	Increased shade seeking and use of sun-protective clothing in intervention groups
Lai et al. (2017) [100]	China (Beijing)	School	RCT	638 students from grades 7, 8, 10, and 11	Educational materials ± two 45-min presentations	Improvements in sun avoidance and shade seeking Improvements in sun knowledge and sun protection behaviors

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Cheng et al. (2011) [101]	China (Beijing)	Community	RCT	285 adult volunteers in Olympic Games	Two 45-min presentations Free sunscreen samples Pamphlets Posters Newsletters	Improvements in suns safety knowledge, and behavior Multicomponent interventions (education, free sunscreen, written materials) more effective than written materials alone
Glanz et al. (1998) [102]	USA (Hawaii)	Community	Observational	6- to 8-year-old children and parents (predominantly White or Asian/Pacific islander) 45 outdoor recreation staff (4.4% White, 42.2% Hawaiian, 26.7% Asian/ Pacific Islander, 26.7% Mixed)	Staff training On-site activities for children Take-home booklets Scoreboards Incentives (gift bags) Free sunscreen	Improved sun protection knowledge, behaviors, policies, and norms
Cassel et al. (2018) [85]	USA (Hawaii)	School	Observational	208 10^{th} grade students 51.6% Asian, 30.4% Native Hawaiian/Pacific Islander, 8.4% White, 3.5% Hispanic, 2.7% Black	30-min presentation Educational brochure UV radiation-sensitive wristbands Hands-on activity Message pen Testimony from local watersports athletes	Improvements in sun protection knowledge No change in sun protection attitudes or intention to tan

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Huh et al. (2021) [103]	USA (Washington and California)	Community	Qualitative	Design experts (n = 11–12) and children and parents from local communities (n = 22–48) Majority were Hispanic or multiracial	Co-design workshops	Development of mobile application incorporating personal data input, virtual games, real-time adaptive messaging, and self-assessments
Zhou et al. (2015) [104]	China (Longyan)	School	RCT	253 college students	Self-regulatory intervention: action and coping plans for sunscreen use Standard care: information on sunscreen use alone	Increased intention to use sunscreen in intervention group
Deponte et al. (2021) [105]	Brazil (Sao Paulo)	School	Semi-experimental	32 8th grade students Self-reported skin phenotype: 49.5% White, 44% Brown Self-reported skin type: 35.48% type 1 and 2	Dialogical workshops with teachers followed by educational program with students Education program included 10 weekly meetings (90 min each), incorporating active teaching/learning methods	Increased sunscreen use and knowledge (e.g., amount of sunscreen to apply, lack of UV protection provided by glass)

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Mahler et al. (2007) [106]	USA (San Diego, California)	School	RCT	133 undergraduate students 45% Caucasian, 35.3% Asian, 11.3% Hispanic	UV photograph, photoaging educational material, or combination of both	Increased sun protection intentions Decreased skin darkening Participants exposed to photoaging information had greater increase in sun protection behavior and decrease in skin darkening at 1-year follow-up
Tuong et al. (2014) [107]	USA (Northern California)	School	RCT	50 high school students Appearance-based group: 12% White, 88% Non-White; 24% burns easily/difficult to tan, 16% tans after initial burn, 60% tans easily/difficult to burn Health-based group: 4% White, 96% Non-White; 20% burns easily/difficult to tan, 24% tans after initial burn, 56% tans easily/difficult to burn	Educational videos, either appearance-based (photoaging) or health-based (skin cancer)	Greater increase in sunscreen adherence in appearance-based than health-based group Improved knowledge on sunscreen and UV exposure in both groups

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Hernandez et al. (2014) [74]	USA (Chicago, Illinois)	Community	Observational	80 Hispanic adults recruited from beauty salons	3-min educational videos, either emphasizing photoaging or skin cancer prevention	Increased perceived susceptibility to skin cancer 74/80 participants regarded skin cancer prevention video as more persuasive Greater interest in prevention of photoaging among women than men
Brinker et al. (2018) [108]	Brazil (Ponte Nova)	School	Observational	356 students in grades 8–12 43.9% FST I-II, 56.1% FST III-VI	Mobile application to simulate future effects of UV exposure on photographs of the face for each student + discussion on UV protection	More than 90% of students motivated to increased sun protection and avoid tanning bed use following intervention Greater effect observed in female participants Effectiveness and reception were similar in FST I-II vs FST III-VI
Brinker et al. (2020) [109]	Brazil (Itauna)	School	RCT	1517 students in grades 9–12 Intervention group (n = 734): 6.3% FST I or II, 34.9% FST III, 50.1% FST IV, 8.6% FST V Control group (n = 839): 8.3% FST I or II, 34.9% FST III, 50.2% FST IV, 6.6% FST V	Mobile application to simulate future effects of UV exposure on photographs of the face for each student + discussion on UV protection	Increased sunscreen use and skin self-examination Decreased tanning behavior

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Robinson et al. (2011) [70]	USA (Chicago, Illinois)	Community	Qualitative	120 adults across 12 focus groups (40 African American, 40 Hispanic, 40 Asian), recruited from community health centers and faith-based institutions	2-h discussion on skin cancer, American Cancer Society educational brochure, illustrative photographs of melanoma in individuals with SOC	Improved recognition of the risk of sunburn and skin cancer in darker skin types
Chao et al. (2017) [112]	USA (Chicago, Illinois)	Clinic	Observational	100 adults recruited from dermatology clinic Targeted intervention (n = 50): 78% African American, 10% Asian/Pacific Islander, 12% Hispanic; 6% always burn/ never tan, 6% usually burn, rarely tan, 36% rarely burn, usually tan, 34% never burn/ always tan Comparison intervention (n = 50): 78% African American, 12% Asian/Pacific Islander, 10% Hispanic; 2% always burn/never tan, 2% usually burn, rarely tan, 48% rarely burn, usually tan, 38% never burn/always tan	Melanoma educational intervention with conventional pamphlet or targeted intervention with SOC-specific information	Greater increase in skin self-examination and knowledge of warning signs for skin cancer in targeted intervention group Increased knowledge on association between sun exposure and melanoma in both groups

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/skin type (if reported)	Interventions	Selected findings
Tsai et al. (2018) [113]	USA (Cleveland, Ohio)	Clinic	RCT	143 African American adults recruited from dermatology clinic	Educational brochure ± online melanoma tutorial	Improved sun protection behavior in educational brochure + online tutorial group only Increased perceived risk of melanoma, knowledge on skin self-examinations, and understanding of melanoma features in both groups
Ho et al. (2016) [114]	USA (Chicago, Illinois)	Clinic	RCT	300 pairs of caregivers and children (2–6 years old) in pediatric clinic Intervention group (n = 153): Ethnicity, 26.1% Hispanic, 71.9 Non-Hispanic; Race, 64.7% White, 13.1% Black, 12.4% Asian/Pacific Islander, 5.3% Mixed; FST, 74.5% I-II, 20.3% III-IV 4.6% V-VI Control group (n = 147): Ethnicity, 27.9% Hispanic, 72.1% Non-Hispanic; Race, 76.9% White, 12.2% Black, 6.8% Asian/Pacific Islander, 1.4% Mixed; FST, 76.9% I-II, 17.7% III-IV, 5.4% FST V-VI	Multicomponent intervention with read-along book, swim shirts, and weekly text-message reminders provided to caregiver	Increased sun protection behaviors in intervention group Increased spectrophotometer-measured melanin (suggestive of tanning) in control group but not in intervention group

Table 2 continued

Author & year	Country or region	Setting	Design	Sample size & race/ethnicity/ skin type (if reported)	Interventions	Selected findings
Norman et al. (2007) [115]	USA (San Diego, California)	Clinic	RCT	819 adolescents aged 11–15 in primary care clinic Intervention group (n = 395): Ethnicity, 2.3% Asian/Pacifica Islander, 4.6% African American, 0.8% Native American, 11.6% Hispanic, 62.3% White, 18.5% Multiethnic/Other; Self-reported sun sensitivity, 26.8% high, 46.1% moderate, 27.1% good natural protection Control group (n = 424): Ethnicity, 4.0% Asian/Pacifica Islander, 8.5% African American, 0.7% Native American, 14.4% Hispanic, 54.7% White, 17.7% Multiethnic/Other; Self-reported sun sensitivity, 23.6% high, 42.0% moderate, 34.4% good natural protection	Stage-based counseling, feedback reports, printed educational material	Improved sun protection behavior (sun avoidance, sunscreen use) and progression to action/maintenance stage of health behavior change in intervention group

USA, United States of America; *SOC,* skin of color; *UV,* ultraviolet; *RCT,* randomized-controlled trial; *FST* Fitzpatrick skin type.

adiation ought to consider the convenience and affordability of modalities to maximize patient adherence. From a methodological perspective, studies involving racially and ethnically diverse participants (e.g., in the United States) have tended to treat race, ethnicity, and skin type of participants as confounders to be controlled for, rather than effect modifiers to be stratified by, and it would be valuable in future analyses to examine whether differences in the acceptability and effectiveness of interventions exist within subgroups with SOC. Digital interventions involving social media and wearable devices present novel methods to encourage health behavior change, whereas the use of systemic photoprotection agents, either alone or in combination with other methods, is an intriguing subject under active research. Finally, given the disproportionately high mortality of melanoma in SOC populations, thought to be due to insufficient screening and delayed diagnosis [28], further high-quality studies examining the presence or absence of a causal relationship between sun exposure and melanoma in SOC are also needed to inform the necessity of photoprotection for primary prevention of melanoma in SOC. These ongoing efforts will be important for guiding proper recommendations and reinforcing photoprotection behaviors for SOC across cultures and continents.

ACKNOWLEDGEMENTS

Funding. No funding or sponsorship was received for this study or publication of this article.

Author Contributions. All authors contributed to the concept and design, drafting, and revision of the manuscript.

Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Data Availability. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest. None declared.

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