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CLINICAL UPDATES IN WILDERNESS MEDICINE

Phototrauma prevention

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In response to an alarming increase in skin cancer rates, much work is being done to find causes, identify populations at risk, and appropriately modify behaviors and protective strategies. The causes of nonmelanoma and melanoma skin cancers are multifactorial; however, the evidence implicating ultraviolet radiation as a major factor is mounting. Sunlight consists of four important wavelengths. Two of them, UVA and UVB, are the most harmful because they cause direct cellular trauma and immunologic suppression. Sunburn is a delayed prostaglandin-mediated erythema that implies severe damage to DNA in a cumulative fashion. Avoidance recommendations include activity planning strategies, apparel choices, and sunscreen use. Clothing is generally protective and hats should cover highly exposed areas. Special apparel products incorporate UV protection into the fabric and offer an additional strategy for workers and enthusiasts who frequently venture into the outdoors. A sunscreen is a topical agent that provides protection against UV radiation. Specifics of sunscreen classification and labeling by the Food and Drug Administration are covered in this article, along with selection and application strategies for outdoor adventurers and travelers. Whereas ultraviolet radiation avoidance and sunscreen use are vital, public education will remain the cornerstone of an effective plan to reduce skin cancer rates.

Introduction

The world's population is being increasingly exposed to ultraviolet radiation (UVR) from the sun, placing us at increased risk of UVR-induced skin cancers.[1] Suntans have become fashionable since the 1950s. There has been a recent explosion of outdoor adventure–seeking hobbyists with a new ''feel as good as you look'' attitude. The use of tanning beds is now widespread in the United States. This is due, in part, to the cosmetic industry and effective, often misleading marketing.[1–3] An increasingly aging population is seeking the fountain of youth.[1] While there has been growth in research and knowledge about the harmful effects of UVR, it remains a primary cause of multiple skin disorders (sunburn, skin aging, wrinkles, and cancer).[2,4] The incidence and prevalence of skin cancer is increasing on a worldwide scale.[5] The public is more aware of the risks, yet insists on a ''healthy tan.'' [3] The concept of photoprotection is complex and can be confusing to medical professionals and consumers.[6,7] This article will review the basics of UVR-related skin damage and offer recommendations for the use of sunscreens and other protective strategies.

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Sunlight

Sunlight encompasses all bands of the electromagnetic spectrum, much of which is blocked by ozone, oxygen, and water vapor in the atmosphere.[4,7] Ultraviolet wavelengths less than 290 nm are absorbed most heavily. Ultraviolet C exists from 220 to 290 nm and is nearly completely blocked. There are 4 biologically important wavelengths that occur from 290 to 10^6 nm. Ultraviolet B (UVB; 280–315 nm) and ultraviolet A (UVA; 315–400 nm) are the most damaging to skin.[1,7] Visible light occupies the 400–760-nm range and usually has no harmful effects. Infrared exists from 760 to 10^6 nm as heat and, while it has few known harmful effects, it comprises 40% of total solar radiation reaching the skin and may potentiate UVB-induced damage.[7]

Ultraviolet A

Ultraviolet A comprises 95% of all solar UVR.[7] It is the principal wavelength emitted by tanning beds. It has erroneously been called the ''safe portion'' of the electromagnetic spectrum. It is less dangerous but penetrates deeper into the skin and has a synergistic effect with UVB. Ultraviolet A is present in >1000 times the concentration of UVB and varies less with time of day and

altitude. It is the primary cause of chronic phototrauma (wrinkles, etc).[2] Early protective products did not affect UVA penetration.

Ultraviolet B

Ultraviolet B is the most biologically important wavelength of the electromagnetic spectrum. Despite comprising only 5% of UVR, it is a major cause of skin cancer.[7] It penetrates less than UVA but is highly reactive with macromolecules in the skin. It is also a major cause of acute and chronic phototrauma. Ultraviolet B is potentiated by UVA and less so by infrared.

Basics of UV damage

Direct cellular effects of UVR cause photoaging (dermatoheliosis), DNA damage, and carcinogenesis.[1,8–10] Ultraviolet radiation–induced immunologic suppression leads to a delayed cutaneous response to tumors. Cellular and humoral immune systems are affected.

Mechanism of UV effects

Ultraviolet radiation is absorbed at various depths depending on the wavelength and molecular species at that depth (water, proteins, pigment, lipids, and DNA). It causes primary photochemical changes in molecules. There are also secondary interactions with radical oxygen species.[7,9] DNA is the principal UVR target, exhibiting base-pair structural changes (pyrimidines and purines) as oxygen free radicals damage the DNA structure.[9]

Skin types

An appreciation of skin types is requisite to the understanding of photoprotection principles.[7]

Type 1: never tan, always burn (lightly complected blondes and red heads).
Type 2: frequently burn, may tan after prolonged exposure.
Type 3: burn infrequently and tan easily.
Type 4: rarely burn, tan heavily (Asian, Native American, Latin American descent).
Type 5: darkly complected, darker with exposure (lightly complected African and Indian descent).
Type 6: heaviest pigmentation (darkly complected African descent).

Table 1. Effects of chronic exposure to ultraviolet radiation

- Telengiectasias
- Loss of skin elasticity
- Skin fragility
- Thinning
- Yellow or sallow coloring
- Dryness
- Itching
- Blotchy pigmentation (hyper and hypo)
- Solar lentigines (“liver spots”)
- Wrinkling and sagging
- Senile purpura (microhemorrhages)

Acute damage (sunburn)

Sunburn is a delayed UVB-induced redness in the skin. There is increased blood flow to skin due to vasodilation and induration.[9] Erythema starts at 4 hours and peaks at 8 to 24 hours of constant UV exposure.[7] There is a prostaglandin-mediated inflammatory reaction caused by direct and indirect damage to cells and DNA. Reactive oxygen species are formed.[9] Sunburn implies severe UV damage and failure of UV protection.[7,9,10] Erythema forms the basis of measurement of sunscreen effectiveness (sun protective factor [SPF]) and is a marker for significant UV overexposure. Erythema-producing exposures are known to be risky.[9,10] There are direct links between repeated severe sunburn, melanoma, and nonmelanoma skin cancers.[2] There is no evidence to support safe tanning.[2] To the contrary, it is now widely held that there is no such thing as a safe tan.

Chronic UV effects

Ultraviolet radiation causes cumulative aging effects, which include those listed in Table 1.[8]

Ultraviolet carcinogenesis

There has been a recent increased incidence in the United States of nonmelanoma skin cancers affecting up to 1.2 million Americans per year, resulting in up to 2500 deaths.[2] These lesions include basal and squamous cell carcinomas. Malignant melanoma is associated with the highest mortality of all UVR-related diseases. There are approximately 32 000 new cases per year and 7000 deaths per year.[1] The causes are multifactorial (UV exposure, genetics, immune status), but the body of evidence implicating UVR as a major factor is great.[7] As latitude decreases, melanoma risk increases. A 2-degree decrease in latitude results in a 10% increase in melanoma incidence. There is a higher incidence in lightly complected people who have less melanin. In India, where the predominant skin type is 4 to 5, the incidence of malignant melanoma is 0.2 cases per 100 000. In Australia, with a skin type predominance of 1 to 3, the in-

cidence is 30 per 100 000. The number of primary cancer lesions that occur on covered skin areas is much lower than exposed areas. Men tend to develop lesions on the back and face, whereas the legs are the most commonly affected areas in women.

A child's skin is more UVR sensitive and changes manifest later as skin cancer. Sunburn in childhood is highly associated with adult cancers, especially in type 1 skin.[7] Two episodes of severe acute sunburn double the risk of nonmelanoma skin cancer later in life. More than 2 episodes results in a 10-fold increase in squamous cell carcinoma risk. Additionally, frequent use of high-SPF sunscreen before age 18 reduces lifetime risk of nonmelanoma skin cancer by up to 78%.[7]

General UV-protective measures

AVOIDANCE

Avoidance recommendations include planning outdoor activities to minimize exposure from 10 AM to 4 PM, when the sun's rays are most direct.[3,4,7] In general, if a person's shadow is shorter than he or she is, the risk is great.[7] The UV index from the National Weather Service allows estimation of the degree of UV exposure for a given skin type on a given day and in a given geographical location.[7] It is expressed on a scale of 0 to 15 (15 is maximum burning potential) and can be used as a general guide for planning activities and exposure potential.

CLOTHING

Clothing is generally protective against UVR. Protection is a function of hole size in the weave and not the fabric type.[1,7] Lighter fabrics are cooler but less protective. Denim is the most protective but least comfortable in sun. The SPF decreases when clothing becomes wet.[7] Shrinkage increases SPF since the weave becomes tighter. To determine the protection afforded by an article of clothing, perform a simple test. Hold the article up to a light bulb.[1] If you can see images through it, the SPF is less than 15. If light gets through but no images are seen, the SPF is 15 to 50. If the clothing blocks all light, the SPF rating is greater than 50.

Hats should cover the most highly sun-exposed areas. Wide (3–7 cm), completely brimmed hats are best.[2,9] The least protective are the baseball-style hats with mesh backs.

Newer clothing products have incorporated UV protection within the fabric, seemingly circumventing the problems of standard apparel with high SPF rating. Some of these products tout a 30+ SPF that is mechanically built in to the weave of the fabric rather than being applied as a chemical coating. These products are advertised as medical devices and, according to a 1994 study,[12] appear to offer significant UV protection against premalignant and cancerous lesions in an animal model.

TANNING

Tanning is a natural defense against UVR. It stems from a UV-induced increase in melanin within the dermis. The increased pigment confers UVB protection. However, intentional tanning is not a good strategy.[7] Since it is known that it requires DNA damage to trigger the tanning process and that this damage leads to long-term exposure risk in a cumulative fashion, there can be no safe level of UVR exposure.

SYNTHETIC TANNING

Topical tanning products contain dihydroxyacetone and have no photoprotective qualities.[1] They only serve to give a false sense of security. Tanning occurs through a reaction with proteins in the skin that creates an orange hue but offers no UV protection.[1,2] Studies are ongoing to develop water-soluble melanin substitutes that, when incorporated into cosmetic compounds, darken the skin and offer some UV protection.[2,11]

EXPOSURES

Patient education and minimizing exposures are key to decreasing the incidence of skin cancers. The general public does not associate many common activities with UVR exposure risk. These include leisure walks, gardening, short trips from the car to a store, and sunlamp and tanning bed use. There is increased participation in outdoor activities every year, placing even more people at higher risk. People must change their mindset.[3] In addition to the use of sunscreen agents, they must be informed about the use of shade, umbrellas, and clothing to prevent overexposure. Wilderness and adventure enthusiasts are at particular risk due to the frequency and cumulative effect of repeat exposures in the face of environmental extremes and few resources to protect them. Adventure travelers can minimize exposure times and severity by recognizing the importance of solar protection during the pretrip planning process. Proper timing of high-risk activities, use of sun-protective clothing, wearing proper eye protection, and the frequent application of high-SPF sunscreens on exposed surfaces are essential elements of a solar-protection plan.

SUNSCREEN

A sunscreen is any chemical or physical agent which, when applied to the skin, provides protection against UVR.

Classification of sunscreens

There are several ways to classify sunscreen products. Chemical photoabsorbers absorb, and physical blockers reflect UVR.[7] Many older preparations were inorganic physical blockers that contained either zinc oxide or titanium dioxide. Many newer substances can be classified as organic photoabsorbers. However, some modern products also contain micronized forms of zinc oxide and titanium dioxide.

Sunscreen families

Para-aminobenzoic acid (PABA) was one of the first chemical sunscreens. It was associated with a high rate of contact sensitivity[7] and was highly water-soluble, making its protection short-lived. PABA discolored clothing and is rarely used today. Related compounds without the problems associated with PABA are now commonly used. Included are cinnamates and salicylates.[3] Cinnamates are relatively water insoluble and are associated with a low rate of sensitivity reactions. Salicylates are considered weak UV absorbers but have a low rate of dermatitis and are highly water insoluble.

Newer compounds extend the protective spectrum of sunscreens to include most of the UVA range. These include the benzophenones (oxybenzone), anthranilates (ensilizole), and dibenzoylmethanes (avobenzone, Parasol 1789). Among these, only the benzophenones offer significant UVB protection. These chemicals are usually combined with other ingredients to produce more effective, broad-spectrum products.[13]

Sunscreen terminology

Sunscreen terminology can be confusing. A *sunblock* is any agent with an SPF rating of 15 or more. This term is not included in new Food and Drug Administration (FDA) guidelines for product labeling.[13] No agent blocks 100% of UVR.[1] A product's UVB absorptive ability can be correlated to the SPF rating[1]: SPF-15 absorbs at least 92%, SPF-30 absorbs at least 96.7%, and SPF-40 absorbs at least 97.5% (old rating).

Minimum erythema dose

The minimum erythema dose (MED) is defined as the minimum quantity of UVR required to cause visible erythema.[2] It varies according to skin type (10 minutes in fair-skinned to >60 minutes in heavily pigmented skin), geographical location, and season. It is useful in the determination of the SPF.

Sun protective factor

The SPF allows for quantifiable comparison between products.[10] It is defined as a ratio[1]:

$$\text{SPF} = \frac{\text{MED in Sunscreen-Protected Skin}}{\text{MED in Non–Sunscreen-Protected Skin}}$$

With an SPF-4 sunscreen, a person who burns at 30 minutes can extend exposure time to 2 hours. An SPF-30 product gives 15 hours of theoretical burn protection in the same person in the same conditions. However, in reality, this person burns more quickly due to UVA potentiation of UVB effects.[10]

Effects on aging

Most information related to aging and UVR exposure is based on animal studies. It indicates that daily use of products with good UVA coverage can prevent wrinkling and sagging.[7] Recent studies support similar effects in humans. Some new products contain vitamins C and E, which act to scavenge free radicals. These products claim to protect against chronic sun-related aging.[2]

Sunscreens and cancer

It is well accepted that skin cancer is largely due to UV-induced changes in DNA dimers.[6] It is also acknowledged that sunscreens prevent DNA damage.[4,6] Therefore, it stands to reason that sunscreen use will help prevent skin cancer. However, there has been little hard data to support this contention until recently. Two studies provided good evidence for this contention. Separate American and Australian studies looked at prevention of precancerous lesions by sunscreen use. The American[14] study showed an overall 36% reduction in annual actinic keratosis formation with sunscreen use. Australian results were comparable.[15] Trials for melanoma prevention and sunscreen use have not been done for obvious ethical and practical reasons.

Ultraviolet radiation risk groups

Certain groups should pay particular attention to UV protection. Winter and high-altitude activity enthusiasts are at greater risk since reflection from snow gives a more constant exposure and windburn exacerbates UVR effects. High altitude diminishes some protection since

the atmosphere is thinner. The ozone layer is usually less dense during winter. General outdoor enthusiasts are also at increased risk. Examples include runners, cyclists, hikers, golfers, and tennis players. Risky occupations include the military, ranchers, police, farmers, construction workers, roofers, surveyors, highway crews, and adventure travelers.

Labeling of sunscreens

The FDA states that, as of December 2002, the maximum labeled SPF should be 30.[11,13] Reasons cited include the additional cost of ultrahigh SPF with little additional benefit. There is concern for potential harm from increased sensitivity reactions. The cost/risk-to-benefit analysis may weigh against the use of ultrahigh SPF products. Under new FDA guidelines, products with an SPF rating from 2 to12 are considered to offer *minimal* sunburn protection. *Moderate* protection is obtained from products with an SPF of 12 to 30. *High* sunburn protection is afforded by products with an SPF rating of 30 or more.

Terminology referring to a product's ability to be used in water is now in common use. *Water-resistant* and *waterproof* or *very water-resistant* mean the product is effective after up to 40 and 80 minutes of immersion, respectively. A sunscreen that is effective against UVB and UVA is labeled *broad-spectrum* or *full-spectrum.*[13]

Factors affecting sunscreen effectiveness

The effectiveness of sunscreens is diminished by sweating, rubbing, and water immersion. There is an inherent time-dependent loss of effectiveness that is independent of mechanical factors and necessitates frequent reapplication. Multiday exposures lead to cumulative UV-related skin damage. Skin sensitivity to the sun is increased on repeated days, making sunscreen effectiveness difficult to predict based on published SPF and exposure data. Higher SPFs may be required to achieve adequate protection.

Sunscreen application recommendations

Outdoor enthusiasts are encouraged to become familiar with types, spectrums, SPF ratings, and delivery vehicles of the numerous sunscreen products. Selection of a sunscreen and the frequency of reapplication are unique to the individual and should be based on the type of activity and surface area to be covered. The durability and water-resistant properties of a sunscreen depend on the type of delivery vehicle in which it is formulated. Lotions and creams are used in the most popular products due to ease of application and flexibility of formulation. However, low durability and the ''greasy'' texture of high-SPF-rated preparations may limit their usefulness for outdoor activities. Older zinc- and titanium-containing compounds may still have a role on occasions when there is a need for high efficacy and durability on a limited surface area and the importance of aesthetics is low. Most sporting and outdoor activities include some level of increased physical exertion and sweating, making sunscreens with good water-resistant properties important. The perfect sunscreen for the adventure traveler would be an easy-to-apply product with a high SPF and good water resistance that covers a large surface area with relatively small quantities. It would be formulated in a durable, nongreasy delivery vehicle and come packaged in a small, break-proof container. General recommendations for the effective application of sunscreen products are listed in Table 2.

Table 2. Sunscreen application recommendations

1. Apply liberally to exposed areas 15–30 min prior to exposure[9,10]
2. Frequent reapplication (every 1–2 h) is recommended, especially for minimal and moderate SPF products.
3. Apply high-SPF lip balm every hour and after drinking or eating.[9]
4. Use gel-based formulation with children.
5. Avoid alcohol-containing preparations.
6. Use zinc oxide for highly exposed areas (nose and ears).
7. The average adults uses 1 oz per application.
8. A family of 4 uses 4 oz or ½ bottle.

Medical photosensitivity

People with some special medical disorders require maximum protection and education.[7] These disorders include lupus, melasma, porphyria, and polymorphous light eruption. Some examples of topical and oral preparations of medications that can cause photosensitivity are listed in Table 3.

Conclusion

Public education efforts use mass media campaigns to decrease skin cancer incidence.[3] Government agencies and professional organizations sponsor many of these efforts. Most programs target women since their traditional family role makes them generally more likely than men to purchase and apply sunscreen products. They emphasize that parents must be role models.[3] However, attitudes will be slow to change. The true measure of

Table 3. Medications that cause photosensitivity

Alprazolam	Dapsone	Methotrexate
Amantadine	Diltiazem	Minoxidil
Amiodarone	Diphenhydramine	Nifedipine
Benzoyl peroxide	Fluoroquinolones	Piroxicam
Carbamazepine	Fluorouracil	Quinidine
Chlordiazepoxide	Glyburide	Tetracyclines
Chloroquine	Gold salts	Thioridazine
Chlorpromazine	Griseofulvin	Tolbutamide
Chlorpropamide	Hydrochlorothiazide	Tretinoin
Clomipramine	Hydrocortizone	Triameterene
Coal tar	Ibuprofen	Trimethaprim-Sulfamethazole (TMX-SMZ)
Dacarbazine	Isotretinoin	Vinblastine

success for these efforts will be the future incidence of skin cancer. Children who are taught early to consider protection from the sun a normal part of their daily routine will constitute a generation with overall decreased rates.

Professional education programs stress the clinician's role in public awareness. As has been learned from the study of tobacco education, a simple suggestion from a physician can have a lasting impact on a patient's perceptions and actions. While technology and research will lead to newer and more effective sunscreens, the most lasting benefit will come from our willingness to use them.

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