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Sunscreens

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Excessive exposure to ultraviolet (UV) radiation can cause erythema, photoaging, and skin cancer.[1,2] Sunscreens are widely used to reduce these risks, but questions remain about their effectiveness and safety. In 2021, the FDA proposed a rule that would require additional safety studies for some sunscreen active ingredients and mandate better UVA protection in sunscreen products.[3]

UVA and UVB — UV radiation is classified based on wavelength as UVB (290-320 nm), UVA2 (320-340 nm), and UVA1 (340-400 nm). UVA, which makes up 95% of terrestrial UV radiation, penetrates the dermis and causes long-term damage. UVB, which is mostly absorbed in the epidermis, is largely responsible for the erythema of sunburn. Both UVA and UVB radiation can cause photoaging, hyperpigmentation, and skin cancer.[4] UVB is strongest at midday; in temperate climates, it is present primarily in late spring, summer, and early autumn. UVA is relatively constant in sunlight throughout the year and, unlike UVB, is not filtered by clear glass.[5]

SPF/BROAD SPECTRUM RATINGS — The sun protection factor (SPF) is the ratio of the amount of UV radiation required to produce a minimally detectable sunburn on sunscreen-protected skin to the amount required on unprotected skin. The amount of erythema-producing UV radiation (primarily UVB) that penetrates through a sunscreen product to reach the skin is affected by factors such as exposure time, intensity of solar energy, and the amount applied. When properly applied, a sunscreen product with an SPF of 15, 30, or 50 allows 1/15, 1/30, or 1/50, respectively, of erythemogenic UV photons to reach the skin.

There is no specific rating system in the US for how much UVA protection is provided by sunscreens. The FDA has allowed sunscreens to be labeled "broad spectrum" if they protect against UVA and UVB and the UVA protection is proportional to the UVB protection; it has now proposed requiring that sunscreen products with an SPF ≥15 offer greater UVA protection (UVA1/UV ratio ≥0.7) in order to be labeled broad spectrum.[3]

Manufacturers of broad-spectrum sunscreens with an SPF ≥15 can claim that their products reduce the risk of skin cancer and photoaging if used as directed with other sun protection measures. The FDA and the US Preventive Services Task Force (USPSTF) both recommend use of a broad-spectrum sunscreen with an SPF ≥15.[6] The American Academy of Dermatology recommends use of a broad-spectrum, water-resistant sunscreen with an SPF ≥30.[7] The FDA has proposed a maximum labeled SPF value of 60+ because data showing that sunscreen products with SPF values >60 provide additional clinical benefits are lacking.[3]

Concerns have been raised that the current rating system for commercial sunscreens is misleading with regard to the actual protection provided against the adverse effects of sun exposure. In addition, some inorganic sunscreen products include non-FDA-approved organic filters (e.g., butyloctyl salicylate), listed as inactive ingredients, to boost the SPF.[8]

Key Points: Sunscreens

- Sunscreens that protect against UV radiation reduce the risk of sunburn and photoaging, and regular use has been associated with a reduced risk of some skin cancers.
- Tinted sunscreens add protection against visible light, which can cause hyperpigmentation.
- Use of a broad-spectrum sunscreen with an SPF ≥30 is recommended by the American Academy of Dermatology.
- Sunscreen should be applied 15 minutes before sun exposure and reapplied at least every 2 hours and after swimming or sweating. Most adults require about 1-2 ounces to fully cover all sun-exposed areas.
- Organic sunscreens are absorbed systemically; whether long-term use could result in adverse health effects is unclear.
- Use of the inorganic sunscreens zinc oxide and titanium dioxide is unlikely to result in systemic absorption or toxicity.
- The organic sunscreens oxybenzone and octinoxate have been removed from many sunscreen products because they may be harmful to the environment.

Table 1. Some FDA-Approved Sunscreen Active Ingredients

Ingredient	UV Protection[1]
Organic	
Cinnamates	
Octinoxate (octyl methoxycinnamate)	UVB
Salicylates	
Homosalate	UVB
Octisalate (octyl salicylate)	UVB
Benzophenones	
Oxybenzone (benzophenone-3)	UVB, UVA2
Others	
Avobenzone (butyl methoxydibenzoyl methane, *Parsol 1789*)	UVA2, UVA1
Ecamsule[2] (terephthalylidene dicamphor sulfonic acid)	UVA2, UVA1
Ensulizole (phenylbenzimidazole sulfonic acid)	UVB
Octocrylene	UVB
Inorganic	
Titanium dioxide	UVB, UVA2, UVA1
Zinc oxide	UVB, UVA2, UVA1

UVB = 290-320 nm; UVA2 = 320-340 nm; UVA1 = 340-400 nm
1. S Abdel Azim et al. J Am Acad Dermatol 2025; 92:677.
2. *Mexoryl SX*, patented by L'Oreal.

In the amounts customarily applied to skin, no sunscreen product provides the labeled degree of protection. The FDA requires that SPF values be determined after applying 2 mg/cm^2 of the product. At 2 mg/cm^2, a 4-ounce container provides 2-4 whole body applications for an adult. Studies have shown that consumers usually apply 0.5-1.0 mg/cm^2 or less. Applying 0.5-mg/cm^2 doses of sunscreens labeled SPF 30-100 has been shown to provide an actual SPF that is about 25% of the labeled SPF.[9]

ACTIVE INGREDIENTS — Organic – Several organic sunscreens that absorb different wavelengths of UV radiation are approved by the FDA (see Table 1). **Avobenzone** is an effective UVA1 absorber, and it also absorbs some UVA2, but it is photolabile; its efficacy decreases by about 60% after 60 minutes of exposure to sunlight. **Oxybenzone** absorbs both UVB and UVA2. **Octinoxate** is a potent UVB absorber, but it is photolabile. **Octisalate** and **homosalate** are weak UVB absorbers; they are generally used with other agents as photostabilizers. **Octocrylene** absorbs UVB and UVA2 and is photostable; when combined with other sunscreens, it can improve the photostability of the entire product. **Ecamsule** is photostable and absorbs both UVA2 and UVA1.[10,11]

PABA (*para*-aminobenzoic acid) and trolamine salicylate are not considered GRASE (generally recognized as safe and effective) by the FDA and are no longer available in sunscreen products sold in the US.[3]

Bemotrizinol *(PARSOL Shield;* also sold as *Tinosorb S, Escalol S)***,** a photostable UVA and UVB filter that has been available in Europe and Australia for many years, is under review by the FDA and may be available in 2026. In a preliminary trial in healthy adults, maximal application of a sunscreen formulation containing 6% bemotrizinol did not result in meaningful systemic exposure (only 13 of 299 plasma samples showed quantifiable bemotrizinol).[12]

Inorganic – The two FDA-approved inorganic sunscreens, zinc oxide and titanium dioxide, block UVB, UVA2, and UVA1 penetration, and they are photostable. Zinc oxide offers better UVA protection than titanium dioxide. Used together, they provide broad UV protection.[13] Nanoparticle formulations are now widely used because they are less visible on the skin, but they may also be less effective.[14]

OTHER INGREDIENTS — In addition to UV filters, tinted sunscreens, which are often available in a variety of shades to match different skin colors, contain **iron oxide** pigments (and less commonly non-nanosized pigmentary **titanium dioxide)** that physically block visible light (400-700 nm). Visible light can induce erythema in light-skinned people and pigmentary changes in dark-skinned people and may play a role in photoaging and some photodermatoses.[10,15]

Antioxidants such as vitamins E and C and niacinamide are added to sunscreen products to reduce oxidative stress caused by UV radiation and increase photoprotective effects,[16,17] but they are not very stable and it is unclear whether they retain their activity when they penetrate the skin. Some **plant-derived extracts** with antioxidant effects have also demonstrated photoprotective activity *in vitro* and in animals. Green tea extract, carotenoids such as beta-carotene, lycopene and lutein, and *Polypodium leucotomos* extract (PLE; derived from a South American species of fern) have been shown to reduce sunburn intensity and improve signs of photodamage in humans, but data are limited.[18]

FORMULATIONS — Sunscreen dosage forms that the FDA has proposed to classify as GRASE include oils, lotions, creams, gels, butters, pastes, ointments, and sticks. Wipes, towelettes, body washes, and shampoos are excluded for lack of data. Sprays and powders require additional testing. Sunscreen sprays are flammable, and burns requiring hospitalization have been reported. Based on animal models, the small particles in sprays and powders could pose inhalation risks.

Table 2. Some Sunscreen Products[1,2]

Product[3]	Formulation	Active Ingredients	Cost[4]
SPF 15			
Australian Gold Spray Gel SPF 15 (Australian Gold)	Spray (8.0 oz)	Avobenzone 2%, octisalate 5%, octocrylene 2%	$10.99
Badger Clear Zinc Lip Balm SPF 15 (W.S. Badger)	Stick (0.15 oz)	Zinc oxide 8%	8.40
Banana Boat Dry Oil SPF 15 (Edgewell)	Spray (9.5 oz)	Avobenzone 1.5%, homosalate 5%, octocrylene 3.5%	12.49
Cetaphil Daily Facial Moisturizer SPF 15 (Cetaphil)	Lotion (4.0 oz)	Avobenzone 3%, octocrylene 10%	19.49
Coppertone Tanning with Vitamin E SPF 15 (Beiersdorf)	Lotion (8.0 fl oz)	Avobenzone 2%, homosalate 5%, octisalate 4.5%, octocrylene 3%	12.99
Hawaiian Tropic Sheer Touch SPF 15 (Edgewell)	Lotion (8.0 fl oz)	Avobenzone 2%, homosalate 3%, octisalate 2%, octocrylene 3%	9.99
Sun Bum Original SPF 15 (Sun Bum)	Lotion (8.0 fl oz)	Avobenzone 2%, homosalate 5%, octisalate 2%, octocrylene 10%	18.49
SPF 30			
Australian Gold Botanical SPF 30 (Australian Gold)	Lotion (5.0 fl oz)	Titanium dioxide 3%, zinc oxide 3%	17.95
Badger Active SPF 30 (W.S. Badger)	Cream (2.9 fl oz)	Zinc oxide 18.75%	15.99
Banana Boat Sport Ultra SPF 30 (Edgewell)	Lotion (8.0 fl oz)	Avobenzone 2.7%, homosalate 6%, octisalate 4.5%, octocrylene 4.5%	7.97
CeraVe Hydrating Tinted[5] SPF 30 (CeraVe)	Cream (1.7 fl oz)	Titanium dioxide 5.5%, zinc oxide 10%[6]	13.97
Hawaiian Tropic Weightless SPF 30 (Edgewell)	Spray (6.0 oz)	Avobenzone 2% homosalate 5.5%, octisalate 4.5%, octocrylene 4%	9.99
Kiss My Face Bare Naked Mineral SPF 30 (Kiss My Face)	Spray (6.0 fl oz)	Titanium dioxide 7.8%	14.64
Neutrogena Invisible Daily Defense SPF 30 (Neutrogena)	Lotion (5.0 fl oz)	Avobenzone 1.5%, homosalate 5%, octisalate 4%, octocrylene 6%	12.74
Sun Bum Original SPF 30 (Sun Bum)	Spray (6.0 oz)	Avobenzone 3%, homosalate 10%, octisalate 5%, octocrylene 3.75%	19.99
SPF 50(+)			
All Good Tinted SPF 50 (All Good)	Butter (1.0 oz)	Zinc oxide 25%[6]	11.00
Anthelios Melt-In Milk SPF 60 (La Roche-Posay)	Lotion (3.0 fl oz)	Avobenzone 3%, homosalate 10%, octisalate 5%, octocrylene 7%	25.99
Babyganics SPF 50 (Babyganics)	Spray (6.0 fl oz)	Titanium dioxide 3.5%, zinc oxide 7.25%	10.98
Banana Boat Kids Sport SPF 50+ (Edgewell)	Lotion (6.0 fl oz)	Titanium dioxide 4.5%, zinc oxide 6.5%	12.79
Coppertone Kids Tear Free SPF 50 (Beiersdorf)	Lotion (8.0 fl oz)	Octinoxate 7.5%, octisalate 5%, zinc oxide 14.5%	7.98
Hawaiian Tropic Everyday Active SPF 50 (Edgewell)	Lotion (8.0 oz)	Avobenzone 2.7%, homosalate 9%, octisalate 4%, octocrylene 5%	8.79
Neutrogena Beach Defense Water + Sun Protection SPF 50+ (Neutrogena)	Stick (1.5 oz)	Avobenzone 3%, homosalate 15%, octisalate 5%, octocrylene 10%	9.88
Sun Bum Original SPF 50 (Sun Bum)	Lotion (8.0 oz)	Avobenzone 3%, homosalate 10%, octisalate 5%, octocrylene 10%	18.49

SPF = sun protection factor
1. Sunscreens are available in primary sunscreen products and are also found in many cosmetic products, including facial moisturizers, lip balms, foundations, and powders and sprays marketed for application over makeup.
2. All of the listed products contain ingredients that allow them to be labeled as providing broad-spectrum UV protection (see Table 1).
3. Individual retailers may carry their own brands of sunscreen.
4. Cost according to cvs.com, amazon.com, or walmart.com. Accessed June 2, 2025.
5. Available in multiple shades.
6. Also contains iron oxides, which provide protection against visible light (400-700 nm).

PREVENTION OF SKIN CANCER — Long-term daily sunscreen use (combined with other sun-protective measures) has been shown to reduce the risk of some nonmelanoma skin cancers.[19] Using a sunscreen with a high SPF may prevent DNA damage to the skin even when the amount applied is less than optimal.[20]

Melanoma – Fair skin, use of tanning beds, and a history of sunburn are associated with increased melanoma risk.[6] In an Australian population-based, case-control study that included 603 adults 18-39 years old with a first primary cutaneous melanoma diagnosis and 1088 controls 18-44 years old, regular sunscreen

use in childhood and early adulthood was associated with a reduced risk of cutaneous melanoma.[21] In a prospective trial, 1621 Australians 25-75 years old were randomized to use an SPF 16 sunscreen either daily or in a discretionary manner (generally 0-2 times weekly) for 4 years. Daily sunscreen users had 50% fewer new primary melanomas (11 vs 22) and 73% fewer invasive melanomas (3 vs 11) than discretionary users 14 years after randomization.[22] In a US case-control study, high cumulative lifetime sun exposure was associated with an increased risk of cutaneous melanoma in subjects with medium or dark skin, but not in those with fair skin.[23]

SAFETY — Organic – All organic sunscreens, especially oxybenzone, can cause contact allergic and photoallergic reactions, but severe reactions are uncommon.[24] Estrogenic and anti-androgenic activity and neurotoxicity have been reported *in vitro* and in some animal studies.[25] These agents penetrate the epidermis and are absorbed systemically; detectable levels have been reported in human plasma, urine, breast milk, amniotic fluid, and fetal and cord blood.[26]

Two randomized, open-label trials were conducted by the FDA to determine whether the active ingredients in some commercially available sunscreen products are absorbed systemically.[27,28] In the first trial, a sunscreen product was applied under maximal use conditions (2 mg/cm^2 every 2 hours [4 times per day] to 75% of body surface area) for 4 days; the 4 active ingredients studied (3% avobenzone, 4-6% oxybenzone, 2.35-10% octocrylene, 2% ecamsule) reached mean maximum plasma concentrations that exceeded the FDA threshold for safety testing (>0.5 ng/mL) and they remained in plasma for at least 3 days after the last application.

In the second trial, the sunscreen product was applied once on day 1, followed by maximal application on days 2-4. Mean maximum plasma concentrations after a single application were >0.5 ng/mL with all 6 of the active ingredients studied (3% avobenzone, 4-6% oxybenzone, 6-10% octocrylene, 10-15% homosalate, 5% octisalate, 7.5% octinoxate); the highest levels occurred with oxybenzone (85-94 ng/mL). All of the active ingredients had long terminal half-lives (mean range 27.3-157.4 hours); concentrations of homosalate and oxybenzone were >0.5 ng/mL in >50% of participants at 21 days.

Whether such exposure could affect hormone levels or result in other adverse effects in humans is unclear.[26,29] The FDA has stated that additional studies are needed to determine the clinical significance of these findings. A study in 441 healthy women found an association between oxybenzone exposure and urinary markers of kidney dysfunction.[30]

Inorganic – Studies have found that titanium dioxide and zinc oxide nanoparticles either do not penetrate or minimally penetrate the stratum corneum and underlying layers of skin, suggesting that systemic absorption and toxicity are unlikely.[31,32] The FDA has stated that available evidence supports a GRASE classification for zinc oxide and titanium dioxide.[3]

Benzene – In 2021, an independent laboratory (Valisure) tested 293 samples of commercially available sunscreens and after-sun products and found that 14 (4.8%), mainly sprays, contained benzene, a known carcinogen, at concentrations above 2 parts per million (the maximum allowed by the FDA).[33] According to the FDA, the contamination may be related to inactive ingredients such as isobutane (a spray propellant); some aerosol sunscreen products with high benzene concentrations have been recalled, and certain manufacturers are now required to test their products for benzene contamination.[34] A retrospective analysis of data from the National Health and Nutrition Examination Survey suggested that the risk of systemic benzene exposure from sunscreen use may be low in US adults.[35]

Environmental Safety – Hawaii, Key West (Florida), the US Virgin Islands, and some other tourist destinations (e.g., Aruba, Palau, Bonaire) have passed ordinances and/or legislation banning the sale of sunscreens that contain oxybenzone and/or octinoxate because they can cause coral reef bleaching.[36] The US Virgin Islands has also banned octocrylene. The FDA intends to evaluate the potential environmental effects associated with use of oxybenzone and octinoxate in sunscreen products.[37] Detectable concentrations of sunscreen active ingredients have been observed in some fish species and adverse reproductive effects have been reported.[38] Nanoparticles of zinc oxide and titanium dioxide may also have detrimental effects on the environment, including coral bleaching.[39]

INFANTS AND CHILDREN — Sunscreen use should generally be avoided in infants <6 months old. A broad-spectrum sunscreen with an SPF ≥30 is recommended for children >6 months old during any sun exposure that might burn unprotected skin. Inorganic sunscreens are less likely than organic sunscreens to cause irritation and sensitization.[7,40]

PREGNANCY — Data on sunscreen use in pregnancy are limited. The results of human and animal studies suggest that the endocrine-disrupting effects of oxybenzone may result in reproductive toxicity, including adverse effects on fetal growth[41,42]; an association between maternal oxybenzone exposure and Hirschsprung's disease in their offspring has been observed.[43] Inorganic sunscreens are generally preferred for pregnant women.

VITAMIN D AND SUNSCREENS — The UVB dose is the most important factor in vitamin D synthesis. The amount of UVB required for production of vitamin D is very small and is much lower than the amount that produces sunburn.[25] Most people require only 2-8 minutes of unprotected exposure to summer sun to maximize synthesis of vitamin D_3.

Whether sunscreen use could lead to vitamin D_3 deficiency is unclear. Two reviews have evaluated the association between sunscreen use and vitamin D_3 levels. Although sunscreen use decreased vitamin D_3 production in some experimental studies, most randomized, controlled field trials found no change in vitamin D_3 levels with daily application of a sunscreen with an SPF of ~16.[44,45] A controlled study in subjects on a 1-week sun holiday found that optimal SPF 15 sunscreen use prevented erythema and increased vitamin D production; synthesis of vitamin D was greater with use of a sunscreen product with a high UVA protection factor compared to one with a low UVA protection factor because it allowed more UVB transmission.[46] No trials have evaluated the effects of high-SPF sunscreens (SPF ≥50) on vitamin D_3 synthesis.

APPLICATION — For maximum efficacy, sunscreen should be applied 15 minutes before sun exposure and reapplied at least every 2 hours and after swimming or sweating. Water-resistant sunscreens remain effective for 40 or 80 minutes while swimming or sweating; no sunscreens are waterproof. Sunscreen should be applied to all sun-exposed areas, using 2 to 3 tablespoons of sunscreen for the entire body and 1 to 2 teaspoons for the face and neck.[16] An appropriate dose of spray sunscreen can be difficult to determine; spraying the sunscreen until the skin glistens and then rubbing it in has been recommended.[7]

With Insect Repellent – When using both a sunscreen and an insect repellent, the sunscreen should be applied first. Applying the insect repellent *N,N*-diethyl-*m*-tolumide (DEET) after sunscreen has been shown to reduce the SPF of the sunscreen, but applying DEET before sunscreen may increase absorption of DEET. Use of products containing both a sunscreen and an insect repellent is not recommended because the sunscreen may need to be reapplied more often and in greater amounts than the repellent.

OTHER SUN PROTECTION MEASURES — In addition to sunscreen use, The American Academy of Dermatology recommends seeking shade during hours of peak sunlight (10am-2pm) and wearing sun-protective clothing, including long-sleeve shirts, pants, wide-brimmed hats, and sunglasses with UV protection. Factors that affect the level of UV protection from clothing include fabric color, fabric type, and tightness of the weave. The ultraviolet protection factor (UPF) is a measure of how effective a fabric is at blocking UV radiation; UV protection is considered very good with a UPF rating of 30-49 and excellent with a rating of 50+.[47] Washing clothes once with *RIT Sun Guard,* a commercially available laundry product containing a broad-spectrum UV absorber *(Tinosorb FD)*, can confer a UPF of 30 that lasts through 20 additional washings. ■

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