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Review Article

# Are sunscreens necessary in Hong Kong?

# 在香港生活有使用防曬產品的必要嗎？

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Despite the relatively low-risk of skin cancer in Hong Kong (latitude 22°N), photo-protection remains an important health strategy to reduce photoaging and photo-immunosuppression. UVA, UVB and infrared wavelengths damage the skin through a variety of cellular and biochemical mechanisms. These can largely be mitigated by appropriate photoprotection: 1) minimising UV exposure, particular during summertime from 10.00 to 14.00 hours, 2) wearing appropriate clothing, hats and sunglasses, and 3) the effective use of sunscreens. A broad spectrum SPF50+ sunscreen should be applied daily, 30 minutes before going outdoors and re-applied immediately before going outside. The risk of vitamin D deficiency is not significantly increased with real-life sunscreen use.

儘管皮膚癌的風險在位處北緯22度的香港相對較低，但日光防護仍是一個不可忽略的個人健康策略，以減少光照引起的皮膚衰老及免疫抑制。長波紫外線（UVA）、中波紫外線（UVB）和紅外線的波長，可通過各種細胞和生化機制損傷皮膚。這些損害大體上都可通過適當的日光防護緩解，包括：1）盡量減少暴露在紫外線下的時間，尤其是在炎夏的上午十時至下午二時；2）穿著合適的衣服、帽子和太陽鏡及3）有效使用防曬產品。廣譜的SPF50+防曬產品可每天使用，應先在外出活動前三十分鐘塗上及出門時再塗一遍。防曬霜在日常生活中的實際使用，並不見有明顯增加維生素D缺乏的風險。

**Keywords:** Photo-immunosuppression, photoaging, photocarcinogenesis, photoprotection, UVA, UVB

**關鍵詞：**光免疫抑制、光衰老、光致癌、光照保護、長波紫外線、中波紫外線

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## Introduction

Hong Kong is fortunate in having a relatively low prevalence of melanoma and non-melanoma skin cancer (crude incidence rate 12.5 per $10^6$ population);[1] so why bother with sunscreen use?

Although sunlight is essential for healthy living, in excess it has significant adverse effects. The acute reactions to sunlight include sunburn (erythema), phototoxicity (e.g. to plants or medications),[2] a variety of photodermatoses (e.g. polymorphic light eruption),[3] and sunlight can aggravate a number of common skin disorders such as rosacea and melasma. However, of greater concern to dermatologists are the effects of chronic ultraviolet (UV) exposure, namely photoaging, photo-immunosuppression and photo-carcinogenesis.

It takes 8 minutes for sunlight to travel 150 million km from the sun to earth, bringing with it 174 petawatts of energy ($174 \times 10^{15}$ watts). The amount of radiation reaching ground level is greatest during summer daylight hours, especially between 10 am and 2 pm (solar zenith), when the rays are most perpendicular to the ground. Other factors that influence this are altitude (4% more UV for every 300 m elevation), latitude (3% more per degree of latitude – Hong Kong's latitude is 22° N), the amount of reflection (e.g. sand reflects 15-30% of UV, whilst snow reflects 90%), clouds, and pollution. Shade can reduce UV radiation by 50-95%.

## Ultraviolet radiation (UVR) and Infrared (IR)

In the UV range of solar radiation, the shorter UVC wavelengths (100-280 mm), are theoretically the most dangerous, as they are highly mutagenic to skin cells, but they do not penetrate past the epidermis. In practice, however, all UVC is filtered by the ozone layer in the stratosphere.

UVB (280-320 nm) makes up less than 10% of total UVR (and only 0.5% of total energy from the sun), but is responsible for a number of significant biological processes including sunburn, sun tanning, vitamin D3 synthesis, immunosuppression and carcinogenesis. UVB is absorbed by various chromophores in the epidermis, including melanin, cellular DNA, vitamin D, and a variety of proteins, lipids and amino acids.[4] UVB is mutagenic, both through direct damage to DNA and indirectly by disrupting DNA repair mechanisms.

Longer wavelength UVA is divided into shorter UVA2 (320-340 nm) and longer UVA1 (340-400 nm). UVA intensity is largely independent of time of day or year and can penetrate through clouds and window glass. Although UVA1 causes less immediate inflammation (sunburn), it penetrates more deeply into the dermis, impairs the normal functioning of immune cells, and affects blood vessels and collagen fibers. UVA1 can also indirectly damage cellular DNA through generation of highly reactive oxygen species (ROS), including superoxide anion, hydrogen peroxide, and singlet oxygen. These ROS activate cytokine and growth factor receptors, which in turn induce transcription factor activator protein 1 (AP-1) and NF-kB. These regulate the expression of pro-inflammatory cytokines, such as interleukin (IL)-1b, TNF-$\alpha$, IL-6, and IL-8.[5,6]

In addition to the damaging effects of UV, we now recognise that the infrared spectrum (700 nm-1 mm), which accounts for 50% of the sun's energy, can also damage skin by stimulating the formation of reactive oxygen species (ROS), as well as causing mutations in mitochondrial DNA (mtDNA).

## The chronic effects of UVR

Photoaging is sun-induced, premature aging of the skin that is superimposed on the normal chronologic aging process. It is influenced by skin type, ethnicity,[7-9] geography, occupation and lifestyle.[10-11] Photoaging can be characterised on a scale from minimal to severe.[10-12] It manifests as wrinkles, lentigines, telangiectasia, coarse texture, loss of translucency, sallow colour, laxity, and decreased elasticity of the skin. More severe photoaging causes deep furrows, leathery appearance, severe atrophy, open comedones, elastosis, and actinic purpura.

Photoaging occurs earlier, and is more obvious, in populations with fair skin (e.g. Fitzpatrick skin phototype I-II versus IV-V). A recent study has shown the onset of wrinkles in French women occurs 10 years before that in Chinese women.[9] The features of photoaging can be diminished by rigorous sun-protection practices. Asian women that fastidiously avoid exposing their face to the sun, by wearing large brimmed hats, carrying parasols, and avoiding the beach or other outdoor activities, have significantly less photoaging.[11,12]

Both the innate and the adaptive immune systems can be affected by UVR. UV radiation alters the skin 'biome', as well as affecting keratinocytes, Langerhan cells, T cells, macrophages, granulocytes, and mast cells. Some of these effects are, however, beneficial; for example, phototherapy is used to treat psoriasis and atopic eczema. This works by triggering apoptosis of skin-infiltrating, pro-inflammatory cells and promoting immune regulation by reducing CD4+ and CD8+ T cells and increasing FOXP3+ $T_{reg}$ cells.[13,14]

The most serious consequence of chronic UVR is skin cancer. The first stage of photo-carcinogenesis is initiation, through formation of cyclobutane pyrimidine dimers. This is followed by promotion and then progression, often due to loss of DNA repair, and further genetic instability. Eventually this leads to metastasis and death.

## Photoprotection

Most of the adverse effects of sunlight can be avoided by effective photoprotection.[12] There are three basic steps in sun protection: first is behaviour; minimise the time spent in the sun, particularly during peak UV times (10 am-2 pm, depending on season and location). Strategies should include scheduling school sports in the early morning or late afternoon, seeking shade under trees, in the lee of buildings or under parasols, or simply by turning your back to the sun.

Clothing is the next step in sun protection: wear long sleeve shirts and trousers/skirts made of materials/fabrics with high ultraviolet protection factor (UPF). In general, thicker, heavier fabrics that are more tightly woven have higher UPFs. Polyester is generally more protective, followed by wool, nylon, and silk. Cotton and linen have lower UPFs. Darker coloured fabrics often have higher UPF than lighter fabrics. Wear wide-brimmed hats and sunglasses.

The third step is sunscreens. From the development of the first commercial sunscreens (benzyl salicylate/benzyl cinnamate) in the 1920s, there are now over 50 chemicals and plant extracts, which have useful sun protective properties. Sunscreens work by either blocking or absorbing UV energy. Previous descriptors of sunscreens include physical/inorganic or chemical/organic sunscreens, but these terms are not entirely accurate; it is more appropriate to use the terms soluble and insoluble.[15]

## Sunscreens (see Table 1)

Insoluble filters, such as titanium dioxide and zinc oxide, work by scattering and reflecting UVR through the formation of an opaque barrier on the skin. Compared to soluble filters, the physical blockers are more photostable, have lower allergenicity, and provide broad UVA and UVB protection.[15] Titanium dioxide is slightly better at blocking UVB, whilst zinc provides more UVA protection; both block some visible light, making them helpful for photosensitivity dermatoses. The cosmetic acceptability of titanium and zinc can be improved by reducing the particle size to 10-50 nm (micronised form), making them more transparent. Below 10 nm (nanoparticle form), these filters start to absorb UV energy, with consequent induction of reactive oxygen species, and risk of indirect DNA damage. This can, however, be mitigated by coating the nanoparticles with aluminum oxide ($Al_2O_3$) or silicon dioxide ($SiO_2$).

Soluble (organic) filters work by absorbing UVR, converting the energy to heat. Nearly, all organic UV sunscreens absorbers have aromatic moieties. Para-aminobenzoic acid (PABA) is the most potent UVB filter and binds well to keratinocytes, which allows it to withstand prolonged water immersion and perspiration. However, it stains skin and concerns over contact allergy saw PABA largely replaced by Padimate-O (which is now rarely used) and various cinnamates. Unfortunately these are significantly less effective, so modern sunscreens combine soluble and insoluble filters to provide broad-spectrum cover. In addition, the soluble sunscreens may be degraded by exposure to sunlight requiring manufacturers to add stabilisers. For example, avobenzone, a UVA1 filter, is often combined with the UVB filters octocrylene, homosalate and octisalate.

Sun protection factor (SPF) is the widely accepted standard for quantifying the UVR protection of sunscreens. This is calculated by dividing the dose of UVR required to produce erythema on sunscreen-protected skin, after application of

**Table 1.** Commonly used organic and inorganic sunscreen filters (list not inclusive)

| Filter name | Type | Peak absorption (nm) | UV spectrum |
|---|---|---|---|
| Aminobenzoates | Organic | | UVB |
| PABA (para-aminobenzoic acid) | | 283 | |
| Padimate-O (octyl dimethyl PABA) | | 311 | |
| Anthralates | Organic | | UVA2 |
| Meradimate (menthyl anthranilate) | | 336 | |
| Benzophenones | Organic | | UVB, UVA2 |
| Oxybenzone (benzophenone-3) | | 290, 325 | |
| Sulisobenzone (benzophenone-4) | | 366 | |
| Dioxybenzone (benzophenone-8) | | 352 | |
| Camphors | Organic | | UVB, UVA |
| Ecamsule (terephthalylidene dicamphor sulfonic acid, Mexoryl SX) | | 345 | |
| Cinnamates | Organic | | UVB |
| Cinoxate (2-ethoxyethyl p-methoxycinnamate) | | 290 | |
| Octinoxate (octyl methoxycinnamate) | | 311 | |
| Dibenzoylmethanes | Organic | | UVA1 |
| Avobenzone (butyl methoxydibenzoylmethane, Parsol 1789) | | 360 | |
| Ensulizole (phenylbenzimidazole sulfonic acid) | Organic | 310 | UVB |
| Octocrylene | Organic | 303 | UVB, UVA2 |
| Salicylates | Organic | | UVB |
| Octisalate (octyl salicylate) | | 307 | |
| Homosalate (homomenthyl salicylate) | | 306 | |
| Trolamine salicylate (triethanolamine salicylate) | | 260-355 | |
| Titanium dioxide | Inorganic | 400 - varies | UVB, UVA2, visible |
| Zinc oxide | Inorganic | 400 - varies | UVB, UVA1, visible |
| Iron oxide | Inorganic | Varies | UVB, UVA1, visible, infrared |

2 mg/cm$^2$, compared to without sunscreen; as a guide a SPF-15 sunscreens will absorb 93.3% of UVR, SPF-30 96.7%, and SPF-60 98.3%. Unfortunately most people only apply 0.5-1.0 mg/cm$^2$, so the effective SPF is often between a quarter and a half of the stated value.

Whilst SPF is mostly a measure of UVB protection (80-90%), it does include a component of UVA protection (10-20%). The Federal Drug Administration (FDA) of the United States specifies that any broad-spectrum sunscreen must have a critical wavelength of >370 nm. The critical wavelength is the wavelength below which 90% of the total area under the absorbance curve resides. Other regulators use persistent pigment darkening, an *in vivo* test, to asses UVA Protection Factor (UVA-PF).[16] A further innovative method of determining the effectiveness of sunscreens is the immune protection factor (IPF).[17] This measures the UVR-induced suppression of either the induction, or elicitation, of a delayed-type hypersensitivity response.

In addition to the SPF, substantivity is important to consider. This is the measure of the adherent qualities of the sunscreen, and its resistance to water and sweat. Substantivity is largely determined by the vehicle, whether an oil, lotion, cream, gel, stick, spray, or ointment. The better the substantivity, the more effective the sunscreen. The older term 'waterproof' has now been discontinued in favour of water resistance (which is annotated with a length of time), e.g. water resistant (40 minutes). Sunscreen efficacy may be less in seawater or in hot water (they are not routinely tested in these circumstances).

## How to use sunscreens

The World Health Organisation (WHO) recommends that sunscreen should be applied (at 2 mg/cm$^2$) 20 minutes before sun exposure, and reapplied every two hours, after swimming or bathing. This ideal is rarely achieved. Most real-life studies show that half of patients wait until they have been in the sun for some time, then only apply 20-50% of the recommended amount, and usually miss large areas of sun exposed skin (particularly on the back).[18]

To maximise sunscreen efficiency, use a 500-ml pump dispenser of an SPF 50+ broad-spectrum sunscreen. Apply it first thing in the morning (to face, neck and backs of hands), instead of daily moisturiser or after-shave. Reapply the sunscreen to all sun-exposed skin as you go outdoors. For hairy areas (including a thinning scalp) consider a spray formulation (this needs to be rubbed in). Modern high protection sunscreens will block UVB for most of the day, but UVA coverage starts to fall off after a few hours, therefore reapply at midday and 2 pm. Do not forget to use a lip sunscreen, which should be reapplied more frequently than is required on other sites.

The prevention of photoaging and photo-carcinogensis should start from birth. Almost half of a person's lifetime sun exposure occurs before the age of 20, when skin is most prone to sun damage.[19] A recent Japanese study has calculated that, to maintain healthy skin until 80 years, children should only receive 2.54 minutes of daily summer sun to unprotected facial skin (or 127 minutes when wearing a SPF-50 sunscreen).[20] For these reasons, both the American Academy of Dermatology (AAD) and the American Academy of Pediatrics (AAP)[21] recommend the use of sunscreen for infants of all ages, including those younger than 6 months. They also emphasise sun avoidance and wearing protective clothing. When choosing a sunscreen for infants and toddlers, consider micronised insoluble sunscreens, as these have a lower potential for skin and eye irritation.

## Sunscreen controversies

It is important to acknowledge that there are some concerns around sunscreens. First is whether sunscreen use contributes to vitamin D

insufficiency. Whilst a good UVB filter should prevent any vitamin D formation, in practice, it takes so little UVB to make vitamin D that normal usage of sunscreens does not result in vitamin D insufficiency.[22,23] The exception may be in Fitzpatrick skin type IV/V individuals living at very low latitudes, or lifestyle/cultural factors (e.g. night shift workers, wearing a burka, etc.). However, vitamin D insufficiency is readily preventable by vitamin D supplementation (recommended dose of vitamin D depends upon the nature and severity of the vitamin D deficiency).

A second controversy is the potential for DNA damage from nanoparticles of titanium behaving as absorbing filters, and inducing ROS. This risk is largely mitigated by coating the nanoparticles with aluminium oxide or silicon dioxide.[24] A third controversy is that sunscreens actually increase the risk of skin cancers. Older studies found that patients used sunscreens (with low SPF and no UVA coverage) tended to be sun seekers that spent longer periods of time in the sun, and consequently had quite high UVR loads. Subsequent studies of high-protection, broad-spectrum sunscreens conclusively show a reduction in actinic damage, including photo-carcinogenesis and photoaging.

## Summary

Be wise in the sun for two reasons: 1) The International Agency for Research on Cancer (IARC), a working group of the World Health Organisation, has identified UV radiation as a Class 1 carcinogen. 2) The main contributor to extrinsic aging is sun damage (photoaging). The strategies to reduce photoaging are to minimise sun exposure, particularly from 10 am to 2 pm in the summer, wear appropriate high protection factor clothing, hats and sunglasses, and use sunscreens effectively.

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