

Research Review

EDUCATIONAL SERIES

An Update on Sunscreens

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ABBREVIATIONS USED IN THIS REVIEW

- BCC** = basal cell carcinoma
- NMSC** = nonmelanoma skin cancer
- QALY** = quality-adjusted life-year
- SCC** = squamous cell carcinoma
- SPF** = sun protection factor
- UV** = ultraviolet

This educational resource coincides with soon to be introduced updated Standard for sunscreen products in Australia and NZ, and how these impact on the advice for patients regarding sun protection. The publication discusses the adverse health and cosmetic effects of sun exposure, outlines the updated Standard, and provides important information on sunscreen use for optimal sun protection.

Effects of sun exposure

Sun exposure has an important role in the development of skin cancer. Sunburn throughout life is an important risk factor for melanoma, particularly severe sunburns during childhood.^{1,3} NZ and Australia lead the world with the highest rates.⁴ With 2212 cases registered in 2009, invasive melanoma was the fourth most common cancer in NZ and the sixth most common cause of cancer-related mortality, with 213 and 113 melanoma-related deaths reported among NZ men and women, respectively.⁵ While most melanoma cases are seen in older individuals, it was still the most common cancer among males aged 25–44 years in 2009 and the second most common among females aged ≤44 years.

NMSCs are also more frequently diagnosed in fair skinned individuals living in sunny climates than in Northern Europe. About 45,000 NMSCs are confirmed in NZ laboratories each year, with approximately 20,000 further cases treated without laboratory tests being performed (e.g. by cryotherapy); exact figures on NMSCs are difficult to obtain, as unlike melanoma, reporting of NMSC cases is not required in NZ.⁶ SCC can be fatal if not treated, but is easily treated if identified early. BCC is the most common and least dangerous skin cancer, but can lead to ulceration and destruction of underlying tissue if not treated. While fatality rates are low with NMSCs, they do impose a significant economic burden (see Pharmacoeconomics). Solar keratoses predispose to SCC, and are a marker of high risk of skin cancer as they arise in areas chronically exposed to sunlight.

UV radiation can also lead to:

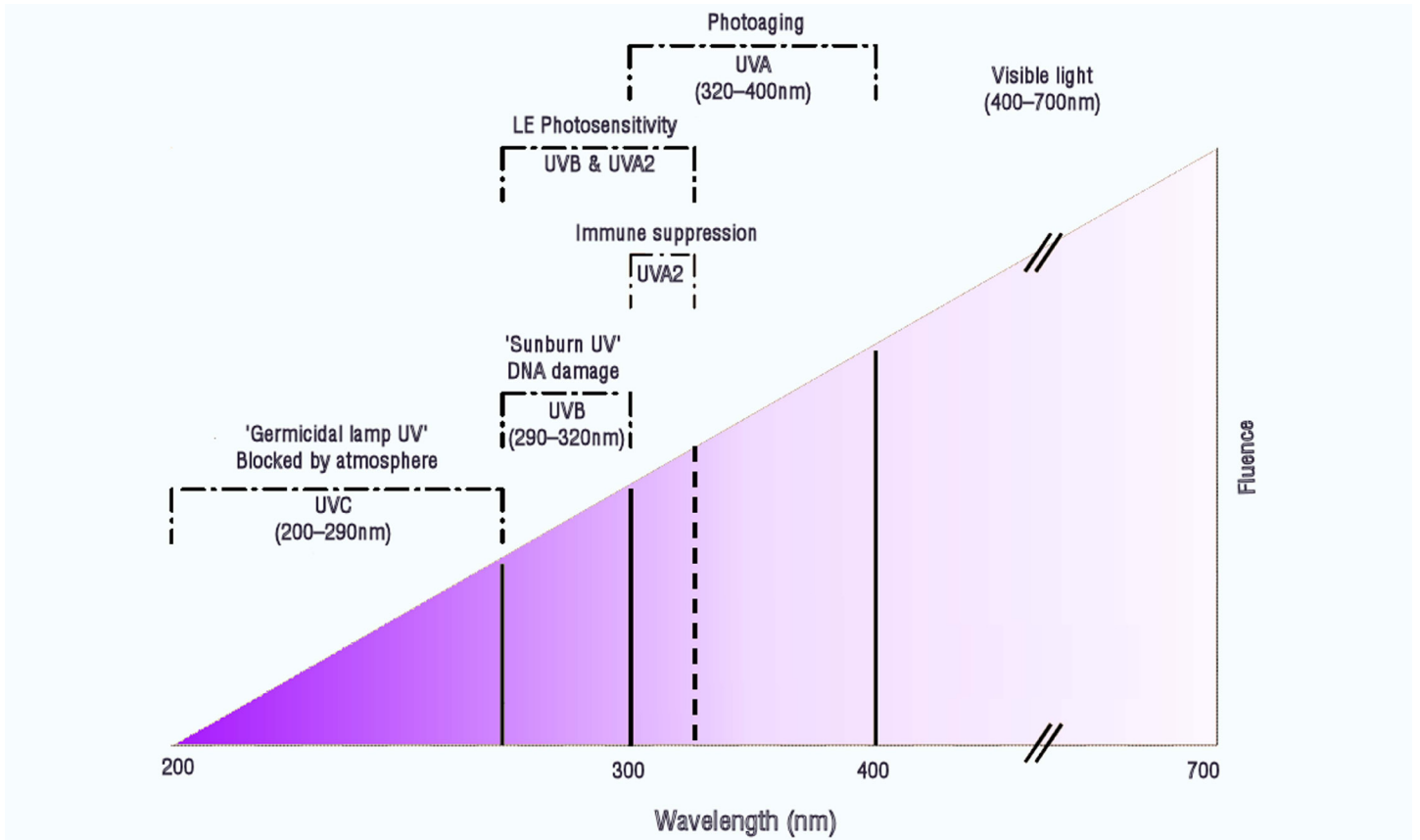
- painful sunburn
- premature skin ageing
- photosensitivity disorders
- eye disease, including cataracts, photokeratitis, photoconjunctivitis and pterygium
- suppressed immune system, e.g. reducing efficacy of immunisation
- non-Hodgkin's lymphoma.

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Solar irradiation

The intensity of UV irradiation reaching an individual, and therefore its biological effects, depends on how much is filtered by the earth's atmosphere. Components of the earth's atmosphere (e.g. oxygen, ozone) filter UV wavelengths from solar irradiation, so the more of these molecules solar irradiation collides with, the greater the UV filtering effect. UV solar irradiation is divided into UVA, UVB and UVC, with UVA1, UVA2 and UVB wavelengths having varying biological effects (see Figure 1).⁷

UV exposure varies according to time of day, time of year and altitude. During the middle of the day when the sun is at its zenith (relative to a specific location), very little UV radiation is filtered due to less atmosphere (shorter distance) for solar irradiation to pass through (Figure 2). The intensity of UV irradiation reaching the earth is therefore higher during the middle of the day than in the mornings and evenings when more solar irradiation is reflected due to passing through more atmosphere before reaching the surface of the earth when the sun is closer to the horizon. The angle that solar irradiation strikes a terrestrial location is also dependent on its position relative to the equator, which changes depending on the time of the year. While NZ's latitude results in solar irradiation reaching us on a greater angle compared with equatorial regions, the tilt of the earth's axis effectively moves us closer to the equator during summer months, and thereby decreases the angle and increases the intensity of solar irradiation. NZ may also be affected by Antarctic ozone depletion during spring, resulting in small increases in UV irradiation. Solar UV irradiation is greater at higher altitudes due to thinner atmosphere.

The UV index is an international standard measurement of UV radiation strength at a specific location and time of day. NIWA provides UV index values for locations across NZ on a daily basis, ranging from peak values of 1 or 2 during the winter months, to peak values of around 12 during the summer months, although values >13 can be reached in the far north. A UV index value of 12 indicates that sunburn typically occurs in about 12 minutes in fair-skinned individuals, a value of 6 indicates a typical burn time of 24 minutes, etc; however, it must be remember that the index is a guide only and other factors (e.g. skin type) need to be taken into account. In addition to publishing UV index values, NIWA also provides Sun Protection Alerts advising the times of the day when sun protection (shade, sunscreen is required, and these are also provided on the MetService website (<http://www.metservice.com/national/index>). More information on the UV index is also available at the NIWA website (<http://tinyurl.com/95oocml>).

Figure 1. UV spectrum and proportional relationship between wavelengths and fluence (adapted from Ting et al)⁷

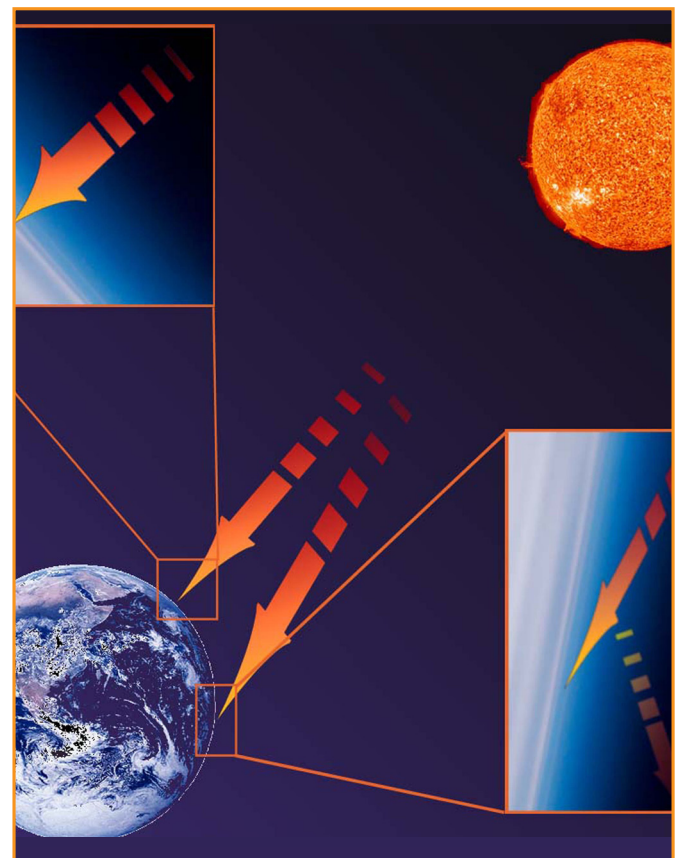


Figure 2. Effect of angle of solar irradiation on atmospheric filtration and reflection

Sunscreen for preventing skin cancer

It is well established that most skin cancers affecting light-skinned individuals are the result of excessive exposure to solar UV radiation, and both clinical studies and basic science strongly suggest that regular, correct sunscreen use can have a role in preventing solar keratosis and SCC.^{9,9} The Nambour trial, started in 1992 in Queensland, Australia, was the first major trial to provide solid evidence that regular sunscreen use (in this study SPF16 sunscreen applied over 4.5 years) decreases the incidence of invasive melanoma, with a 50% reduction seen over 10 years of follow-up.¹⁰ Sunscreens also reduce photoaging, i.e. wrinkles, pigment irregularity, telangiectasia and a sallow complexion.¹¹⁻¹⁴

Sunscreens have typically primarily absorbed UVB radiation, but more recent developments have focussed on chemical absorption of UVA wavelengths as well, which have been identified as a significant risk factor for the development of melanoma.¹⁵ UVA radiation damages DNA and intracellular structures directly and indirectly by creating reactive oxygen species; it also results in suppression of protective immune processes. A product's SPF value (dose of UV radiation [290-400nm] required to produce one minimal erythema dose after application of 2 mg/cm of the sunscreen product divided by the dose needed to produce one minimal erythema dose on unprotected skin) is mainly a measure of its ability to protect against UVB radiation, as UVB has erythemogenicity that is 1000 times greater than UVA.¹⁶ While there is currently no internationally agreed standard for testing and measuring UVA protection, the Australian and NZ Standard now uses UVA-PF and monochromatic protection factor at 380nm. Not all products on the market include optimal UVA protection. For a product to claim broad-spectrum protection (which together with an SPF value provides a measure of both UVB and UVA protection), UVA-PF is required to be $\geq 1/3$ of the labelled SPF and/or protection is against a critical wavelength of ≥ 370 nm.

Individuals at risk of skin cancer because of skin type, photosensitivity or outdoor habits should be strongly encouraged to seek cover or shade, and to wear protective clothing. Appropriate use of broad-spectrum UVA/UVB sunscreen could be considered a significant adjunct to physical forms of UV protection.¹⁵ However, research has shown that sunscreen is often applied too thinly and infrequently (see How to Use Sunscreens). The findings of many studies are complicated by issues surrounding correct sunscreen usage.¹⁷ Sunscreens should not be seen to promote or facilitate increasing how long an individual is exposed to the sun. To help both consumers and health professionals optimise sunscreen use and prevent skin cancers and melanoma, NZ and Australian Standard has recently been updated.

NEW STANDARD

The new version of AS/NZS 2604 Sunscreen Standard, which includes the most significant change in sunscreen standards in NZ and Australia for more than 15 years, has now been published, and will be implemented during 2012 or early 2013.¹⁸ In NZ, these requirements will not be mandatory, and sunscreen products complying with other recognised test protocols will be permitted.

The new joint NZ/Australian Standard (AS/NZS 2604:2012 Sunscreen products – evaluation and classification) recommends an SPF benchmark of 50+, and water resistance levels must now meet world leading requirements. SPF50 ensures 98% protection against UVB when applied correctly. In addition, important restrictions have been placed on the wording that is allowed on sunscreen products, with the following three terms identified as misleading and no longer permitted:

- 'waterproof' – the Standard acknowledges that sunscreens will wash off with water immersion
- 'sunblock' – could be interpreted that 100% of the sunburning radiation is 'blocked'
- 'sweatproof' – 'sweat resistance' is not a substitute for 'water resistance'.

For AS/NZS 2604, there are three requirements for testing in order to support compliance.

1. SPF *in vivo* testing conducted on ten human subjects.
2. Broad Spectrum – interpreted from ratios determined (*in vitro*) in a standardised absorption curve.
3. Water resistance determined up to 4 hours.

The first two apply according to the category of sunscreen (intended use) and the third, separately, for the additional, nonmandatory claim of water resistance when required. Further information on SPF/UVA testing can be found at <http://tinyurl.com/8ky5out>.

Table 1. Testing requirements for SPF categories

Tested SPF	Label SPF claim	Category descriptions	Broad spectrum claim		
			Primary sunscreen	Secondary sunscreen	
				Skin care	Colour or lip
1-3	Not allowed	–	Not allowed	Not allowed	Not allowed
4-14	4, 6, 8, 10	Low protection	Compulsory	Compulsory	Optional
15-29	15, 20, 25	Medium or moderate protection	Compulsory	Compulsory	Optional
30-59	30, 40, 50	High protection	Compulsory	Compulsory	Compulsory
≥ 60	50+	Very high protection	Compulsory	Compulsory	Compulsory

Additional new sunscreen categories are SPF 50 and 50+ (at least 60; see Table 1). Higher SPF, in tandem with the proportionately based new broad spectrum requirements, offers substantially increased consumer protection from both erythema and the premature ageing effects of sunlight.

The revision of the Standard brings true international alignment across most of the test methods used through recognition of the ISO Standard developed for this purpose. Companies are encouraged to quote this Standard against claims of SPF in products sold in NZ, including secondary sunscreen products (e.g. moisturisers and other cosmetic products) as well as primary sunscreen products. The full Standard can be purchased from <http://tinyurl.com/8up6xa6>.

AVAILABLE SUNSCREEN TECHNOLOGIES

Sunscreens protect the skin from UV radiation via two distinct methods – reflection and absorption of UV radiation (see Table 2).^{16,19} Agents that reflect UV radiation (zinc oxide and titanium dioxide) are normally inorganic opaque ointments; microfine titanium dioxide is more cosmetically acceptable, but can still leave a milky appearance on the skin. Chemicals used in sunscreens that primarily absorb UVA/B radiation are organic and have greater cosmetic appeal than those that reflect UV radiation, as they are not visible once applied to the skin. Multiple UV absorbing/reflecting chemicals often constitute a sunscreen product to screen out a broad spectrum of UV radiation.

A 2010 study has reported poor performance of UVA protection among sunscreen products available in Australian and NZ, with weakening UVA protection seen during sun exposure.²⁰ Many of the chemicals used in sunscreens to filter UV radiation are photoreactive, and result in the formation of photoproducts over time as a result of light exposure; some photoproducts can filter UV radiation.¹⁶ The photostability of sunscreen agents can also depend on the other ingredients, including other UV filters and solvents. Newer UV filters used in sunscreens tend to be more photostable, while others can be made photostable by other UV filters or technologies. For example, avobenzene, which is one of the best agents for filtering UVA radiation but has poor photostability, has been photostabilised with oxybenzone, which also adds additional UVA filtering, and diethylhexyl 2,6-naphthalate (DEHN), with the resulting product branded Helioplex™; additional UVB filters are also often added to increase the effective SPF. The aforementioned 2010 study also found that photostability of sunscreen products from NZ and Australia was consistently inadequate in the UVA spectrum, probably due mainly to the inclusion of octinoxate, which is known to enhance avobenzene photodegradation.²⁰ However, one product containing the Helioplex™ technology stood out with 93% photostability (compared with 27–57% for the other seven ‘non-Helioplex™’ sunscreens tested).

Another important aspect of a sunscreen’s performance is resistance to water immersion and sweating. Products intended for Europe or US markets can only make water resistant claims of 40 minutes and 80 minutes.²¹ Testing for water resistance in Australia has required application of the sunscreen to volunteers who then spend time in a spa pool at 31–35°C. The maximum period for water resistance that can be claimed is 4 hours and it is required that this be related to the category of SPF protection achieved. However, the new regulations have brought water resistance levels of sunscreen in Australia and NZ into line with world leading requirements.¹⁸

Newer sunscreen technologies include entrapment of active sunscreen ingredients within a silica shell (microencapsulation), which reduces direct skin contact and associated potential for allergic reactions, and also helps improve compatibility between different ingredients.¹⁶ Polymer materials that enhance the effectiveness of the active ingredients may also be used, specifically ‘sunspheres’, which are tiny styrene/acrylates filled with water that is released upon skin contact and scatters UV radiation thereby increasing its probability of contact with the active ingredients. The SPF can be increased by 50–70% with such technologies. New vehicles mean sunscreen chemicals are also better distributed along the skin surface than was the case with conventional formulations.

Questions have been raised in recent years about the safety of sunscreens.^{22–24} The claims have focussed on the production of reactive oxygen species by nanoparticles from zinc oxide or titanium dioxide penetrating the skin barrier, and also the creation of free radicals as the result of degradation of a number of other sunscreen ingredients. Some sunscreens have had antioxidants added to help neutralise these free radicals. The best available evidence indicates that nanoparticles in sunscreens do not permeate the skin or pass into living skin cells in humans, and are therefore not a health risk. Antioxidants may also provide benefits in terms of UV filtering and destruction of free radicals that form as a consequence of UV radiation and breakdown of other sunscreen ingredients – research into this area is ongoing.

Factors such as fragrance, colour, appearance, sensory profile, packaging and cost are also important in consumer choice for sunscreens and should not be underestimated. Many consumers fail to apply sunscreens as they perceive them as unpleasant in appearance and feel on the skin.

Table 2. Common or well-known sunscreen UV filtering ingredients and their properties^{16,25}

Ingredient name	Mode of protection	Water solubility	Notes
Benzyl salicylate and salicylate derivatives (homosalate, octyl salicylate)	Absorbs UVB	No – can be used in waterproof formulations	Often used in combination with other ingredients
Benzyl cinnamate (and derivatives)	Absorbs UVB	Yes	Often found in combination with other ingredients
PABA (p-aminobenzoic acid)	Absorbs UVB	No – needs to be used in alcohol-based solutions	Used to be used extensively Discolours fabrics Allergic reactions relatively common; most sunscreen are now PABA free
Benzophenones (avobenzene [butyl methoxydibenzoylmethane], oxybenzone, dioxybenzone sulisobenzene)	Absorbs UVB and short-wave UVA	No	Controversy around risk of photocarcinogenicity Avobenzene can be photostabilised with Helioplex™
Cinoxate (2-ethoxyethyl p-methoxycinnamate)	Absorbs UVB and UVA	No	Controversy around risk of photocarcinogenicity
Octocrylene	Absorbs UVB and UVA	No	–
Ecamsule (terephthalylidene dicamphor sulfonic acid)	Absorbs UVA (290–400nm – peak 345)	Yes	Exclusive to L’Oréal and its brands
Drometrizole trisiloxane	Absorbs UVB and UVA (peaks 303 and 344nm)	No	Exclusive to L’Oréal and its brands
Bisotrizole (Tinosorb R)	Absorbs, reflects and scatters UVB and UVA	No	–
Bemotrizinol (Tinosorb S)	Absorbs UVB and UVA	No	Approved in Australia and EU, but not US
Octinoxate (octyl methoxycinnamate)	Absorbs UVB and UVA	No	–
Zinc oxide and titanium dioxide	Absorb and reflect UVB and UVA	No	Less skin sensitivity Zinc oxide blocks more UV radiation than titanium dioxide

HOW TO USE SUNSCREEN

It has been well established that sunscreen use by the general public is often inadequate to obtain optimal efficacy. Australian primary school children of all ages have been shown to apply sunscreen at 0.48 mg/cm², compared with 2.0 mg/cm², the thickness at which it is tested during product development (2.2 mg/cm² in the US).²⁶ Dispensing from a pump increased application to around 0.75 mg/cm², while coverage with roll-on sunscreen was low at 0.22 mg/cm²; coverage with a squeeze bottle was 0.57 mg/cm².

For a sunscreen product to provide the full protection it claims, it needs to be applied liberally 15–30 minutes before going outside to allow time for it to dry and be absorbed into the skin.²⁷ A good guide for achieving adequate coverage for an adult is to apply at least half a teaspoon to each arm and the face (including the ears and neck), and at least a full teaspoon to each leg, the front of body and the back of body; 35mL in total for the entire body.²⁸ Reapplication should be undertaken every 2 hours while outdoors or immediately following swimming or sweating heavily. The UK NICE has also recommended greater use of sunscreens at work and school for the prevention of skin cancer.²⁹ These recommendations should not replace other recommendations regarding reducing sun exposure, including use of brimmed hats, UV filtering sunglasses, protective clothing, avoiding exposure during the hours the sun rays are at their strongest, and being aware of the additive effects of reflective surfaces (e.g. water, snow).

Selecting an appropriate sunscreen is also important. In recent years, the focus has been on ensuring that a selected sunscreen provides UVA as well as UVB protection (broad spectrum). However, not all available sunscreen products that claim UVA protection do so to an adequate degree.²⁰ When choosing a sunscreen, individuals are advised to choose a water-resistant, broad-spectrum product with an SPF of 50 or more, in a formulation that suits the individual. It should also be noted that sunscreens have a limited shelf-life of about 2–3 years, after which they lose efficacy and should not be used. It is therefore important that health professionals are able to identify sunscreens that provide adequate protection and, importantly, are able to pass this information on to their patients.³⁰

DIFFERENT PATIENT GROUPS

Sun protection is more important during childhood than any other time, as sunburn during pre-adult years is a greater risk factor for future melanoma than sunburn during adulthood.¹ Babies' and toddlers' skin is more sensitive and vulnerable to sun damage/injury than adults' skin, and UV radiation can burn their skin after a few minutes of midsummer midday exposure.^{31,32} It is generally recommended that babies are kept out of direct sun whenever possible, and that a protective hat and clothing that restricts sun exposure to as much skin as possible is used, even when in the shade. With respect to vitamin D synthesis in babies, the NZ Cancer Society notes that during daylight savings months, small amounts of sun exposure on small areas of skin in the early morning or late afternoon are sufficient, while during winter *"it is generally safe and advisable for infants to spend some time in the sun"*.³²

While there are sunscreen products that are designed specifically for children and babies, most children and babies can tolerate 'adult' formulations.³¹ Sunscreen can be used at any age when there is unavoidable exposure to the sun, but use should be restricted to limited areas babies aged <1 year. Concern has been expressed that thinner infant skin may absorb a greater proportion of chemicals and that infants have proportionately greater body surface area than adults; however, previous reports advising against sunscreen use on babies have been discredited.^{31,32} Sunscreens suitable for use on babies and children should be broad spectrum, SPF ≥50 and provide at least 2 hours of water-resistant protection if children are swimming or perspiring heavily, with initial application at least 15 minutes before sun exposure and reapplication every 2 hours. Titanium dioxide- or zinc oxide-based sunscreens are less likely to cause skin irritation making them particularly suitable for babies and children with sensitive skin, but if problems arise, medical advice should be sought.

PHARMACOECONOMICS

With skin cancers being the most common type of cancer affecting New Zealanders, the costs are significant. It had been estimated that in 2006, there were 4741 lost life-years (3811 and 930 for melanoma and NMSCs, respectively), \$57.1 million spent in healthcare costs (\$5.7 and \$51.4 million) and \$66.0 million lost in potential productivity costs (\$59.3 and \$6.7 million).³³

Using data from the Queensland Nambour trial,¹⁰ Gordon et al calculated that at a cost of around 70 cents per person, the investment associated with the promotion of sunscreen use in the intervention group saved the Australian government around AU\$85,000 in healthcare costs for the 11 BCCs, 24 SCCs and 838 actinic keratoses that were prevented over the study period.⁹ The same research group recently refined its findings in a cost-effectiveness analysis of daily sunscreen use for preventing skin cancer using a Markov model that utilised a combined household and government perspective.³⁴ It was found that the discounted incremental cost per QALY gained from the sunscreen intervention was AU\$40,890. It was also calculated that 33 melanomas, 168 SCCs and four melanoma-related deaths would be prevented at a cost of approximately AU\$808,000 over the intervention cohort's projected lifetime, and that the sunscreen intervention had a 64% probability of being cost effective at a willingness-to-pay threshold of AU\$50,000 per QALY gained. The conclusion was that the best available evidence suggests probable long-term cost effectiveness of promoting routine sunscreen use in white individuals living in areas of high sun exposure.

WHAT TO LOOK FOR ON THE LABEL

When advising patients on the best sunscreen to choose, there are important things they should look for on the label under the new Standard (see below). All UV filtering agents used in sunscreen products degrade with age, so all sunscreen products should have an expiry date – patients should be advised to never buy a sunscreen product without one. Sunscreens should be discarded 12 months after opening irrespective of expiry date. When buying sunscreen for children, consider sensitive-skin formulations (particularly for babies). In accordance with the new Standard, patients should avoid using any sunscreen product found that uses the term 'sunblock', 'waterproof' or 'sweatproof'.

Important things to look for on the label of commercial sunscreen products

SPF 50+

Broad spectrum

The Standard it was tested against

Water resistance

Expiry date

CHECKLIST/FAQS

- The UV index is measured by NIWA and published daily by the Met Service and media. It measures UV radiation levels at the Earth's surface, and in NZ ranges from 0 to >13. The higher the score, the greater the potential to damage the skin.
- Acute and chronic UV exposure leads to sunburn, photoaging, eye disease and skin cancer.
- Daily sun protection leads to reduced risk of these diseases.
- Those at average risk can make vitamin D by exposing their arms to the sun for a few minutes each day; those at high risk of skin cancer may be best to take supplements.
- When outdoors and the clear sky UV index is ≥ 3 , seek shade and protect skin by covering up with a brimmed hat, long sleeves and pants. Wear UV-protective sunglasses. Apply sunscreen to uncovered skin. Extra protection is necessary if the UV index is ≥ 8 .
- Sunscreens protect fair skin by filtering out damaging UV radiation, reducing the risk of skin cancer and photoaging changes.

If you have fair skin that tans poorly or burns easily, or have a history of skin cancer, when outdoors between September and May:

- apply broad-spectrum sunscreen or moisturiser with SPF 30+ to face and neck daily
- apply broad-spectrum SPF 50+ sunscreen to all exposed skin when outdoors for half an hour or longer between 10am and 4pm
- choose a water-resistant product if swimming or heavily perspiring
- avoid prolonged sun exposure, but if outdoors for longer, reapply sunscreen every 2 hours
- aim to never get sunburned.

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SUMMARY AND CONCLUDING REMARKS/ PRACTISE TIPS

- The rates of melanoma and NMSC continue to rise as the population ages.
- Healthcare practitioners should be advising their young and old patients regarding their risk of skin cancer and the effects of sunburn and lifelong exposure to the sun on the state of their skin and eyes.
- Explain that sun avoidance and the use of clothing are the most effective measures to reduce these risks.
- Provide patients with practical advice – the most expensive sunscreen is not necessarily the best; encourage the use of high or very-high protection broad-spectrum sunscreens on a daily basis during most of the year.

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Publication of this article was supported by an educational grant from Johnson & Johnson Pacific. The content or opinions expressed in this publication may not reflect the views of Johnson & Johnson Pacific. Treatment decisions based on these data are the full responsibility of the prescribing physician.