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# Regular Use of Sunscreen Can Reduce Melanoma Risk

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For the last two decades, the question of whether or not sunscreen use can protect against melanoma has been a topic of hot debate. While the notion is appealing and biologically plausible, various reasons why sunscreen use might not protect people from melanoma and might even *cause* melanoma have been put forward. Most clinicians and researchers on both sides have agreed on one thing, however: that a very large, well-conducted, randomized controlled trial is the only way to provide an answer.

Last year, our research team in Queensland, Australia, published the first clinical trial results regarding sunscreen and melanoma prevention, in the *Journal of Clinical Oncology.*[1] We showed in a Queensland trial that regular use of sunscreen could halve people's risk of developing melanoma. While the trial was not very large, it was conducted over a considerable period. Its results go a long way towards resolving, if not clinching, the debate, and we hope it will assist clinicians in making recommendations about appropriate preventive care.

### Historical Stumbling Blocks

For many years, researchers trying to answer the question of sunscreen's protective potential against melanoma faced a number of stumbling blocks in trying to design a valid, convincing study. The best evidence available until recently was the data from some less than ideal animal and human studies.

*Previous support for sunscreen use in melanoma prevention*

Apart from studies specifically focusing on sunscreen and melanoma prevention, basic science strongly suggested that

*Continued on page 2*

## From the Editors

In the past two years, breakthroughs in the treatment of advanced metastatic melanoma with new immune-directed and targeted therapies have appropriately garnered most of the media and medical attention around the disease. Nonetheless, primary prevention (synonymous with reduction of ultraviolet radiation exposure to the skin) remains the best guarantee against future melanoma deaths. This issue of *The Melanoma Letter* highlights two of the most important components of primary prevention: sunscreen and clothing. In the accompanying pieces, our invited authors provide important insights on these subjects that we anticipate will help you better educate and counsel your patients.

Sunscreen is an essential and preferred form of sun protection for our society, which thrives on outdoor activity and bares at least some skin at all times. Even public health campaigns to downplay the role of sunscreen in favor of sun avoidance and full coverage clothing have retreated to a recognition of a major role for sunscreen. Until recently, the sunscreen

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**Regular Use of Sunscreen,** *from page 1*

sunscreen could help. We have long known that the majority of cutaneous melanomas are caused by excessive exposure to solar ultraviolet (UV) radiation.[2-4] As early as 1957,[3] Lancaster and Nelson attributed causation of many melanomas to solar UV. Therefore, shielding the skin from UV with effective sunscreens along with other sun safety precautions would logically appear to be beneficial in long-term reduction of melanoma formation.

Of course, research has shown that people tend to apply sunscreen too thinly and infrequently,[5] and for decades, even sunscreens that provided excellent protection against the sun's shorter, UVB wavelengths often protected inadequately against the longer, UVA wavelengths. However, by fundamental principles, if proper amounts of effective broad-spectrum UVA/UVB sunscreen were used,[2] it could be considered a significant adjunct to clothing, shade, and other physical means of solar UV protection.[6] It goes almost without saying that this would hold true only if sunscreen were used in the manner intended — to protect skin from the effects of heightened sun exposure, rather than to encourage and facilitate even greater exposure.[7,8]

Beyond basic science, supporting evidence for the benefits of sunscreen against melanoma development were scarce, since reviews of case-control and cohort studies of sunscreen use and melanoma risk were uninformative.[1,6] Some support, however, did come from a randomized trial of sunscreen application in Canadian children.[9] Conducted from 1993 to 1996, it showed a small reduction in new melanocytic nevi, the strongest predictors of melanoma, in children allocated to sunscreen, especially if they had freckles.[9] Other affirming evidence of the long-term benefit of regular sunscreen use against melanoma was indirect; several trials had established that regular sunscreen use could reduce the occurrence of other sun-induced skin tumors, specifically actinic keratoses and squamous cell carcinomas (SCC).[6,10]

### *Previous arguments against sunscreen use in melanoma prevention*

The case *against* sunscreen use has been made many times in the past.[7,11,12] The criticism was based largely on poor non-trial evidence that mainly reflected the lack of reliability in people's self-reports of past sunscreen use (frequency and/or duration). It also suffered from the profound problem of incorrectly inferring causation from association. In linking an increase in melanoma development with sunscreen use, investigators could not properly account for certain confounding factors – e.g., that patients at high melanoma risk (such as patients with many nevi) might be advised to use sunscreen regularly because they are known to be at high risk, thereby making sunscreen use *appear* to be associated with heightened melanoma risk.

This has always been the insurmountable stumbling block for non-randomized studies linking melanoma to sunscreen use. They have been unable to distinguish the main drivers of sunscreen use from those of melanoma causation, since they are one and the same: susceptibility to sunburn, high occupational or recreational sun exposure, and family history of melanoma.[6] Detractors of these studies have also cited the short latency period allowed in case-control studies between reported sunscreen use and the development of melanoma, with the elapsed time insufficient to allow any valid scientific conclusions about causation or protection.[11,12]

*"The Queensland trial showed that regular use of sunscreen could cut people's risk of developing melanoma in half. The results go a long way towards resolving, if not clinching, the debate."*

Another key argument against sunscreen use as a melanoma preventive has been the belief that sunscreen use increases users' time in the sun, thereby potentially increasing their risk of melanoma. This hypothesis was generated by study groups of dedicated European sunbathers who may have used sunscreen to heighten their sun exposure and consequent skin tanning.

Such groups are not using sunscreen the way it is intended, as an adjunct to other physical means of sun protection. Thus, any increase in melanoma risk among them may come from the misuse of sunscreens rather than the properties of sunscreens per se.[6,8]

Other potential safety concerns about sunscreen (e.g., photoactivation of certain ingredients, endocrine disruption, and vitamin D deficiency) have also been raised, but most sunscreens now on the market have been evaluated for safety and efficacy, and the safety concerns have been unsupported by direct human evidence of harm.[6]

## The Nambour Skin Cancer Prevention Trial

The Queensland trial results regarding sunscreen and melanoma came as the culmination of 10 years of follow-up after a 4.5-year randomized controlled trial of 1,621 adults aged 25 to 75 who had been randomly selected from all residents of Nambour, a subtropical Australian township. Trial participants were centrally randomized either to apply a freely supplied broad-spectrum sunscreen with an SPF of 16 daily to the head and arms for 4.5 years, or to continue their usual level of sunscreen use or non-use. We followed study subjects for a decade after the end of the active intervention period by sending questionnaires every year asking about new skin cancers, ongoing sunscreen habits, and average time outdoors, and by monitoring regional pathology laboratories as well as the Queensland Cancer Registry for newly reported melanomas. Sun exposure patterns and history of skin cancer were identical in both treatment groups at baseline owing to successful randomization, and proved to be the same in both groups in the decade-long follow-up.[1]

Ten years after cessation of the sunscreen intervention, the group of 812 people randomized to daily sunscreen use had experienced 11 new melanomas, half the number identified in the control group of 809, who experienced 22 new melanomas. This result was of borderline statistical significance ($p=0.051$). Eleven of the 22 melanomas in the control group were invasive melanomas, compared with only three invasive melanomas among the daily sunscreen users (73 percent fewer) ($p=0.045$).[1] We are uncertain about why the dedicated sunscreen group had a greater apparent decrease in invasive melanomas than in situ melanomas. Possibly, a proportion of in situ melanomas have a different developmental pathway and do not progress to invasive melanoma; or possibly simple chance influenced the findings, given the relatively small number of melanomas diagnosed in our study over all.

Although participants who had been randomized to use sunscreen daily were more likely to continue to do so after the trial than those in the control group (25 percent versus 18 percent), most of the effectiveness could be attributed to the regular sunscreen application *during* the trial,[1] when 75 percent of participants assigned to daily sunscreen use applied sunscreen at least 3 or 4 days per week, compared with 25 percent of the control group.

It is difficult to say how the use of a higher SPF (about SPF 30 or higher) sunscreen in the Nambour Trial might have affected the results, since the study sunscreen (SPF 16) could filter out around 95 percent of the UVB (compared with 97 percent or higher filtered by SPF 30+ sunscreen). (Separately, being a broad-spectrum sunscreen, it also filtered a proportion of UVA wavelengths in sunlight.) Based on previous research, we know that lower than recommended amounts of sunscreen were undoubtedly applied by Nambour Trial participants on average;[5] thus, increasing skin coverage or average thickness of application might have had an increased protective effect. In addition, longer use than the 4.5 years of the trial, or randomizing a much larger number of people to the sunscreen intervention group at the outset, might well have produced stronger results.

Another limitation of the Nambour Trial findings is that they flow from a single trial only: their replication would give further weight to our relatively slim amount of evidence. Furthermore, the trial was carried out only in adults: it would be very reassuring to have more randomized trial evidence of long-term benefit against melanoma for children using sunscreen regularly, even if, like the Canadian study in 2000,[9] the study focused on prevention of melanocytic nevi as an intermediate surrogate for melanoma. Third, our trial was carried out in Queensland, Australia, a relatively sunny part of the world where year-round caution in the sun is highly warranted. Thus, we can only presume that the results would also apply to Northern Hemisphere populations in the summer months or during travel to sunny countries (when sun exposure and risk of melanoma development rise).

## Recommendations for Patients

What advice should we give melanoma patients based on these results? In the Nambour Trial, participants were asked to apply sunscreen to the head (face, ears, scalp if exposed), neck, arms, and hands every morning, and advised to reapply after heavy sweating, bathing, or long sun exposure. The daily sunscreen users also tended to apply sunscreen more regularly to the trunk and lower limbs than the discretionary (control) group did, and we assume this was the reason for the decrease in melanoma across all body sites, not only on the prescribed application sites. Thus, medical professionals can advise that regular application of a broad-spectrum (UVA/UVB) sunscreen with an SPF of 15+ or higher in this fashion is likely to be beneficial for melanoma protection. Clothing should cover those body parts to which sunscreen hasn't been applied. Other supplementary techniques including sun avoidance and/or seeking proper shade in high sun exposure settings should also be recommended. We hope that more behavioral research will be carried out to give us deeper insights into facilitators and barriers to regular sunscreen use and other sun protection behaviors, especially in high sun exposure settings among persons highly susceptible to melanoma.

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**From the Editors**, *from page 1*

strategy was challenged by limited data on its ability to prevent melanoma. In their lead story, Drs. Adèle Green and Gail Williams share the results and implications of their groundbreaking study, the first clinical trial ever to show the benefits of regular sunscreen use in melanoma prevention.

With this new evidence that sunscreen can help prevent melanoma, it behooves sunscreen developers to redouble their efforts; much work remains to be done to create better and more effective sunscreens. In their story, Drs. Steven Wang and Judy Hu discuss these challenges, exploring the many significant improvements made to sunscreens in recent years as well as the improvements that still need to be made to achieve optimum protection.

Finally, despite the reluctance of most Americans to cover up completely, most experts consider clothing to be the single best shield against UVR. In their concluding story, Dr. Peter Gies and Alan McLennan examine just what qualities make clothing an effective form of UV protection, and discuss the relative merits of dedicated high-UPF clothing and everyday clothing.

While improvements in early detection and treatment are needed and ongoing, the best solution to the melanoma problem is to avoid getting it in the first place. For the majority of melanomas, which are sun-related, this means primary prevention with sun protection. We hope this issue will help you in your own sun protection efforts and those of your patients.

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# Challenges in Making an Effective Sunscreen

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Ultraviolet (UV) radiation from the sun has long been associated with the development of skin cancer. The International Agency for Research on Cancer (IARC) has identified UV radiation as a human carcinogen,[1] and nearly 90 percent of non-melanoma skin cancers and 65 percent of melanomas are associated with sun exposure.[2,3] UV radiation also plays a role in accelerating skin aging, inducing immunosuppression, and aggravating photodermatoses. For these reasons, numerous campaigns to improve public attitudes towards UV protection and change behavior have been waged by health care communities, nonprofit organizations, and government agencies.

Comprehensive programs for photoprotection include avoiding excessive sun exposure, seeking shade, wearing sun-protective clothing (including long-sleeved shirts, long pants, UV-blocking sunglasses, and hats), and applying sunscreen. Among these measures, sunscreen remains the strategy most commonly adopted by people spending time outdoors.

Since the introduction of the first commercially available sunscreen in the US in 1928, tremendous advances have been made in sunscreen technology, improving efficacy and safety. The Final Rules on sunscreens, issued by the US Food and Drug Administration (FDA) on June 14, 2011,[4] validated sunscreen manufacturers' long-standing efforts at innovation, above all in improving broad-spectrum UVA/UVB protection. The FDA will now for the first time allow sunscreens with broad-spectrum SPF 15 or higher protection to display on their labels the claim, "if used as directed with other sun protection measures, (this sunscreen) decreases the risk of skin cancer and early skin aging caused by the sun."

It has been a long journey to where sunscreens have arrived today—in a better place than they have ever been. Reviewing how they got here will help us understand just how significant the changes already made have been, and the considerable work that remains to be done to make sunscreens even better.

## Sunscreen History

The first commercial sunscreen was probably developed by chemist Franz Greiter in 1938,[5] but use was not common until 1944, when Benjamin Green[6] sold red veterinarian petrolatum ("Red Vet Pet") to the US Army to protect soldiers in the Pacific theater during World War II. The product had limited effectiveness and was disagreeable to use due to the red color and sticky texture.

In ensuing decades, sunscreens were designed to prevent sunburn and enhance tanning; many were called "tanning oils" or "tanning lotions." Their UV filters blocked only UVB (280-320nm) radiation, often at very low SPFs (ranging from 2 or 3 to perhaps 8). The Skin Cancer Foundation, with its independent volunteer committee of photobiologists, beginning in 1979, was the first organization to clearly establish SPF 15 as the minimum standard for adequate SPF protection. The first UVA filter, a benzophenone,[7] was introduced to manufacturers in the 1960s; however, the first purportedly broad-spectrum UVA/UVB sunscreen was not put on the market until 1980, and *truly* broad-spectrum sunscreens did not emerge until the 1990s. Even after that, no regulatory guidelines existed in the US for testing and labeling the degree of UVA protection, so many products claiming to have UVA or broad-spectrum protection actually offered inadequate protection or none.[8,9]

*"The functional role of sunscreen has progressed from merely preventing sunburn to reducing skin cancers and slowing skin aging."*

It was not until June 2011 when the FDA provided specific guidelines for testing and labeling UVA protection, naming the *in vitro* (lab-based) critical wavelength (CW) method[4] as its test for UVA protection. Only sunscreens with a CW >370nm will be permitted to claim "broad spectrum" status. The critical wavelength test is a laboratory test method using a PMMA (polymethyl methacrylate) plate that measures UV transmission with and without sunscreen: the absorption spectrum of the sunscreen is measured against wavelength. The wavelength where 90 percent of absorption occurs is defined as the critical wavelength. The more potent the UVA protection, the longer the critical wavelength.

## Technologies Used to Create an Effective Sunscreen

In addition to having an impeccable safety profile, sunscreens are expected to prevent both acute and long-term harmful effects of UV exposure. Multiple considerations are factored into the design and making of such products. The two most important objectives are improving the UV absorption profile and enhancing user compliance.

### I. Improving the UV Absorption Profile

Sunscreens with superior UV absorption profiles combine high (magnitude) UV protection with broad-spectrum coverage extending to the long-wave UVAI range (340-400nm). To accomplish this, formulators need to consider both the UV filters and the inactive ingredients in the formulation. Most of the media attention has focused on UV filters, but inactive ingredients such as rheological additives, film-forming polymers, and light-scattering particles play an equal role in overall efficacy. In fact, many of the breakthroughs in modern-day sunscreens come from the addition of novel inactive ingredients; it is often easier to improve sunscreens in this way, since developing and marketing new UV filters are costly, and often hampered by long delays in the FDA approval process.

*UV Filters*

Currently only 17 UV filters, or active ingredients, are approved for use in the US—far fewer than in Europe and Australia. In addition, the allowable concentration of avobenzone, the most potent chemical UVA-I filter in the US, is only 3 percent, compared to 5 percent in Europe, and the FDA does not allow it to be combined with physical filters such as zinc oxide. These limitations pose a challenge for formulators attempting to design products with superior UVA protection.

A number of active filters **(Table 1)** are currently awaiting FDA approval via the Time and Extent Application (TEA) process. With TEA, the FDA can expedite approval of formulations and ingredients that have been available in foreign markets for five years. All of the new compounds fulfill this time requirement, having been marketed in Europe, Asia, and Australia over the last decade. The addition of these new filters would provide formulators with more options and, in theory, create superior products. Unfortunately, some of these products have been in the TEA pipeline for years without notable progress toward approval.

### *Efficacy Enhancers*

Choosing the types and concentrations of UV filters is only the first component in the formulation process. As mentioned, inactive ingredients comprising the delivery vehicle play a major role in efficacy. Vehicles that dissolve and disperse the UV filters uniformly can enhance overall UV protection. Excess UV filters from a poorly formulated product tend to accumulate in the valleys of the skin, leaving poor coverage on the peaks of the skin. This uneven coverage translates to lower SPF protection and often sunburn. In contrast, UV filters from a well-formulated product deliver an even coating to the skin, providing equal coverage to both peaks and valleys and thus better protecting against sunburn. To deliver uniform and even coverage, additives and film-formers (agents such as acrylates, acrylamides, and copolymers that when applied to the skin, leave a pliable, cohesive, and continuous covering) have been developed.[10,11]

Light-scattering additives also boost the overall SPF of products. They scatter incident UV light and increase the distance it has to travel to reach the skin as it passes through the sunscreen layer. According to the Beer-Lambert law, the absorbance of any UV filter depends on the path length that light must travel. Hence, increasing the path length increases the filter's UV absorbance. One example of this principle is the hollow sphere technology developed by Jones et al,[12] composed of styrene/acrylates and copolymer-entrapping water molecules. These polymer spheres scatter light and increase path length.

### *Photostabilizers*

A major weakness of some UV filters is their tendency to degrade after UV exposure; the original molecules convert to isomers, tautomers, or dimers, which are less effective or completely ineffective in providing UV protection. Avobenzone is the only long-range chemical UVA filter (340-400 nm) widely available to sunscreen manufacturers in the US. The molecule is inherently unstable, and by itself, loses nearly 50 percent of its screening capacity after just one hour of UV exposure.[13] Furthermore, the frequent addition of octinoxate, a common UVB filter, to sunscreens containing avobenzone accelerates the degradation of both compounds. However, a number of photostabilizers have been incorporated in sunscreens to stabilize avobenzone. One, the UVB filter octocrylene, is widely used in the US.[9] Another, comprised of octocrylene, oxybenzone, and diethylhexyl 2,6-naphthalate (DEHN), has been shown to provide over 80 percent photostabilization of avobenzone. This combination is patented and trademarked by Neutrogena as Helioplex™. In Europe and Asia, other molecules and UV filters, such as bemotrizinol, 4-methylbenzylidene camphor, and polysilicone, are sanctioned to stabilize avobenzone.

## II. Boosting User Compliance

The UV absorption profile is only one feature of an effective sunscreen. Perhaps every bit as important but less acknowledged are the qualities that inspire usage. These include fragrance, color, appearance, sensory profile, packaging, and last but not least, cost. Collectively, the appeal of these features often determines overall user compliance. It should be self-evident that consumers will not use a product that fails their demands in these areas, even if it has a superior UV absorption profile. At best, consumers will use the product in inadequate amounts and neglect to reapply as directed. The result is poor UV protection.

*Continued on page 6*

| Active Ingredients | Maximum Concentration | Peak Absorption (nm) | UV Action Spectrum |
|---|---|---|---|
| Methylene-bis-benzotriazolyl tetramethylbutylphenol (MBBT) (Tinosorb M) (Bisoctrizole) | 10% | 305, 360 | UVB, UVA |
| Bis-ethylhexyloxyphenol methoxyphenyl triazine (BEMT) (Tinosorb S) (Bemotrizinol) | 10% | 310, 343 | UVB, UVA |
| Ethylhexyl triazone (EHT) (octyl triazone) | 5% | 314 | UVB |
| Isoamyl methoxycinnamate (Amiloxate) | 10% | 310 | UVB |
| Methylbenzylidene camphor (Enzacamene) | 4% | 300 | UVB |
| Diethylhexyl butamido triazone (Iscotrizinol) | 3% | 312 | UVB |
| Terephthalylidene dicamphor sulfonic acid (Ecamsule, or Mexoryl SX) | 10% | 345 | UVB, UVA |
| Drometrizole trisiloxane (Mexoryl XL) | 15% | 303, 344 | UVB, UVA |

**Table 1. Active ingredients pending FDA approval via the TEA process**

**Effective Sunscreen**, *from page 5*

The sensory and tactile modifiers in sunscreens especially influence their appeal. Consumers often complain that most products are too greasy and oily. This poses a challenge to formulators, as most chemical UV filters are oil-soluble molecules. For example, octocrylene, a UVB filter and a photostabilizer for avobenzone, is extremely oily. To compound the problem, most recreational (sport) sunscreen products need to be water-resistant so that they won't wash away with sweat. Formulators use water-resistant polymers such as Bis-PEG-18 methyl ether dimethylsilane, trimethylsiloxysilicate, and butylated PVP (polyvinylpyrrolidone) to form a physical film to help hold the sunscreen oil on the skin's surface. These polymers can create a tacky and greasy feeling that makes sunscreens unpleasant to use.

A variety of ingredients, such as silicones, silicas, and other slipping agents, are added to decrease the tacky and sticky feeling and improve tactile and sensory profiles. Polymeric surfactants, such as acrylate cross polymers, can also serve as both water resistance agents and emulsifiers. These surfactants have rapid emulsion-breaking characteristics that allow consumers to spread the product on the skin easily and evenly, and improve the overall texture after the sunscreen dries.

## Future Trends

A recent industry trend involves the addition of antioxidants to sunscreens. Many manufacturers have embraced the concept and now market products that include vitamin C, vitamin E, and other antioxidants. The scientific rationale is that antioxidants provide a second line of protection against the radical oxygen species (ROS) induced by UV, since conventional UV filters offer incomplete protection. A large reason for inadequate sunscreen protection, however, is simply that many individuals apply inadequate amounts. Furthermore, many products in the US still offer low or no UVA protection. ROS generated from UVA rays have the potential to react with various photosensitizers and generate damage to the DNA, proteins, and lipid membranes of skin tissue. Although the body has natural antioxidant defenses against the ROS, this endogenous system is quickly overwhelmed when faced with excessive oxidative stress. That is one reason it will be so important, now that the FDA has issued its final rules on sunscreen, for consumers to start looking for broad-spectrum UVA/UVB sunscreens that bear the aforementioned label, "if used as directed with other sun protection measures, (this sunscreen) decreases the risk of skin cancer and early skin aging caused by the sun." Only broad-spectrum sunscreens with SPFs of 15 or higher will earn this label.

The concept of adding antioxidants to sunscreen is appealing. However, a recent study by Wang, *et al*[14] showed that the protection against ROS in sunscreens containing antioxidants derives mainly from the UVA filters. The activity level of antioxidants in sunscreens is virtually nonexistent, for a number of reasons, including inadequate antioxidant concentration, inherently unstable formulations, and use of the wrong active forms. Thus, considerable progress is needed before any truly significant benefits can be achieved by adding antioxidants to sunscreens.

## Conclusions

The functional role of sunscreen has progressed from merely preventing sunburn to reducing skin cancers and slowing skin aging. The sunscreen industry continues to develop novel UV filters and innovative vehicles to provide superior UV protection. With additional understanding of the potential dangers of UV radiation, the scientific communities and sunscreen industry will certainly continue to develop innovative, safer, and more effective sunscreens. Dermatologists and other physicians must educate consumers about new products with cutting edge technologies. More importantly, in addressing the public, we should always emphasize that sunscreen use *is only one type of photoprotection.* Avoiding excessive sun exposure, seeking shade, and wearing sun-protective clothing and sunglasses are also essential in reducing overall UV exposure.

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In 1990, after discussions with the Cancer Council Victoria (CCV) regarding how much ultraviolet radiation (UVR) protection was provided by clothing, the CCV purchased a number of items of summer beach wear and sent them for testing to the Australian Radiation Laboratory (later renamed ARPANSA, the Australian Radiation Protection and Nuclear Safety Agency). The test results were surprising, with only a few of the garments achieving a Protection Factor (PF) against UVR greater than 15. This was somewhat comparable to a sun protection factor (SPF) of 15 on sunscreen (at that time the maximum SPF in the Australian sunscreen standards).

Solar UVR levels in parts of Australia often reach extreme UV Index levels in summer,[1,2] and the clothing ideally should have had PFs of at least 40-50 for adequate all-day protection of people with fair skin. The low PF levels found on the tested garments inspired a testing program to seek fabrics and materials providing proper sun protection that could be wholeheartedly recommended to the general public, outdoor workers, and schoolchildren in summer.

## UPF: The Ultimate Measure of Clothing Sun Protection

A major step in the right direction was development of the *ultraviolet protection factor* (UPF) measurement, standardized in Australia in 1996.[3] Based on a laboratory test of the amount of UVR that penetrates fabrics, the measurement quantifies how effectively a piece of clothing shields against the sun, depending on traits including the fabric's content, weight, color, and construction. Since an item of clothing scatters much of the incoming UVR, the test method uses an integrating sphere to capture all of the direct and scattered UVR passing through the clothing. It also employs a spectral measurement system to quantify the amount of UVR transmitted through the fabric at each wavelength across the UV range, since shorter wavelength UVB is about 1,000 times more effective at causing sunburn than longer wavelength UVA.

The term UPF was adapted in lieu of the well-established sunscreen SPF measurement for specific reasons.[3] First, the UPF measurement is based on an *in vitro* test, and the desire was to distinguish it from the SPF test, which is performed on live subjects. Second, UPF signifies both UVA and UVB protection, while SPF is specifically a measure of UVB protection (though broad-spectrum sunscreens with SPFs of 15 or higher protect substantially against both UVA and UVB). A shirt with a UPF of 50, for example, allows just 1/50th of the sun's UVA and UVB rays to reach the skin. Third, the lab UPF test better reflects real-world protection than SPF does. To achieve reasonably accurate test results for sunscreens, the testing thickness is much higher in the lab than what is generally applied outdoors, and substantial research has shown that people rarely apply sunscreen correctly, typically missing spots and failing to apply sufficient amounts. Thus, SPF measurements in the lab are rarely achieved in actual practice.[4] In contrast, clothing tested in the lab may actually have a lower UPF measurement than when it is worn outdoors. Laboratory UPF testing simulates a worst case situation, where the UVR is incident at right angles to the fabric and transmission is therefore maximal. In general wear situations, clothing often provides protection in excess of the UPF rating because the incoming UVR will be at a range of different angles and only at right angles a fraction of the time. Thus, when consumers see a UPF label on an item of clothing, they can be confident about the listed level of protection.

In studies done in Australia, lycra/elastane fabrics were the most likely to have UPFs of 50 or higher, followed by plastic, nylon and polyester.[5] They provide excellent sun protection, in contrast to, e.g., a thin white cotton T-shirt, which has a UPF of about 5, allowing 1/5th of the sun's UVR to pass through—even more when wet. To date, ARPANSA has tested more than 28,000 fabric samples. The most commonly tested types of fabrics are shown in **Table 1,** along with their rated UPFs.

In general, clothing often worn outdoors in high-UVR regions should have a UPF of 50+. This would include, for example, school uniforms and schoolwear, workshirts, high-visibility shirts and vests, swimwear and rash vests (aka rashguards, which usually should exceed UPF 50+ by a considerable margin because their UPF decreases when wet), fishing clothes and associated gear, and police uniforms.

Today, systems for testing and determining UPF are similar around the world. In many countries, including the US, the ASTM International (formerly called the American Society for Testing and Materials) criteria for UPF assessment are used; UPF labels in the US often state that an item meets ASTM International standards. Clothing with a UPF of 30 or higher can also earn The Skin Cancer Foundation's Seal of Recommendation.

## Clothing Traits that Determine Sun Protection

To be absolutely certain of an item of clothing's sun-protective ability, the item has to be UPF-tested. However, in the real world to date, only a limited number of (often designer) clothing items come with UPF labels. Unfortunately, it is difficult to tell how protective clothing is by looking at it or holding it up to the light, because the human eye responds to visible radiation and not to

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| Material | Percent of samples with each UPF rating | | | | | Total # of Items Tested |
|---|---|---|---|---|---|---|
| | None (<15) | 15-20 | 25-35 | 40-50 | 50+ | |
| Lycra/Elastanes | 0.7 | 1.3 | 3.5 | 4.1 | 90.4 | 12,506 |
| Plastic | 7.8 | 2.7 | 3.1 | 3.1 | 83.3 | 449 |
| Nylon | 8.1 | 6.3 | 8.7 | 8.2 | 68.7 | 1,434 |
| Polyester | 4.9 | 6.9 | 15.0 | 12.1 | 61.0 | 4,853 |
| Cotton | 9.0 | 9.6 | 12.1 | 9.3 | 60.0 | 4,511 |
| Polyester/Cotton | 6.9 | 15.6 | 27.0 | 16.1 | 34.4 | 4,955 |

**Table 1. A summary of the most often tested material types and the distribution of their rated UPFs. [For a complete listing of materials tested, go to http://www.arpansa.gov.au/index.htm]**

## Sun-Protective Clothing, *from page 7*

UVR, and the transmission of fabrics in the visible range is often higher than in the UVR range. Even when a clothing item appears to allow little light through, excessive UVR may be penetrating.[6]

Thus, consumers need to consider several key factors when seeking to purchase sun-safe clothes. First, at the most fundamental level, the more skin you cover, the better. A long-sleeved shirt covers more skin than a T-shirt, especially if it has a high neckline or collar that shields the back of the neck; long pants cover more skin than shorts. A wide-brimmed hat protects more of the face than a baseball cap, and close-fitting wraparound sunglasses protect more of the area around the eyes than small lenses do.

However, no matter how much clothing you wear, if the sun penetrates it easily, it's not protective. Fabrics are made of tiny fibers woven or knitted together. Under a microscope, we see spaces between the fibers; UV can pass directly through these holes to reach the skin. The most important single protective factor of fabrics is **cover factor** or **weave density** – i.e., how much of the fabric is actually fiber and how much is open space, through which UVR can pass. **(See Figure 2.)** The tighter the knit or weave, the smaller the holes and the less UVR can get through.

**Composition** of the fabric fibers is also very important, as some materials strongly absorb UVR while others transmit more UVR. Most fibers naturally absorb some UV radiation, and some have elastic threads that pull the fibers tightly together, reducing the spaces between the holes. Synthetic fibers such as polyester, lycra, nylon, and acrylic are more protective than bleached cottons, and shiny or lustrous semi-synthetic fabrics like rayon reflect more UV than do matte ones, such as linen, which tend to absorb rather than reflect UV.

Other key factors include:

- **color:** Darker colors absorb more UVR than lighter colors of the same material, including whites and pastels, but bright, vivid colors such as red can also substantially absorb UVR.[5] Many dyes absorb UVR, which helps reduce exposure, and many white fabrics have "optical whitening agents," chemical compounds that strongly absorb UVR, especially UVA.[6,7]
- **weight** per unit area and fabric **thickness:** Heavier, thicker clothes absorb more UVR. For example, light, sheer silk gauze provides far less UV protection than heavy cotton denim.
- **tension** or **stretch:** More stretch lowers UPF rating.
- **moisture** content: Many fabrics have lower ratings when wet; for example, the UPF of a thin white cotton T-shirt may decrease from 5 to only about 3 when wet.
- fabric **condition:** The more worn and frayed clothing is, the more UVR it lets through.[7]

### Conclusions: Dedicated High-UPF Clothing vs. Everyday Clothing

If someone pays close attention to the aforementioned sun-protective traits and makes purchases accordingly, the right everyday clothing can be highly sun-protective: jeans, for example, have a UPF of about 1700, and you can't do much better than that. It is also worthwhile to know that you can *improve* the UPF of everyday clothing. To begin with, just washing a garment a few times (especially one made from cottons or cotton blends) makes it shrink slightly, closing up holes between the fibers that let through UVR, and thereby increasing the garment's UPF; this is especially true in Australia, where clothes are not washed before UPF testing.

Tests have shown that it is also possible to wash in extra protection with a UV-blocking additive like Rit SunGuard.[6] If you have favorite garments that are not UPF-rated, washing them with certain dyes and chemical additives such as UV-cutting agents (UVCAs) can also increase the UV protection they provide.

However, for measurement and certainty purposes, UPF-rated clothing is obviously superior, since the consumer knows exactly how much protection he or she is getting. Furthermore, it is designed specifically to be more sun-protective as its *raison d'etre,* while everyday clothing may focus more on fashionability, sex appeal, and comfort. In any event, the latest versions of UPF clothing can also be extremely fashionable and comfortable while offering better coverage: slightly longer sleeves, light, breathable fabrics with a double layer at the shoulders (a high-UVR-exposure area), or other design factors may provide extra comfort and coolness as well as better sun protection.

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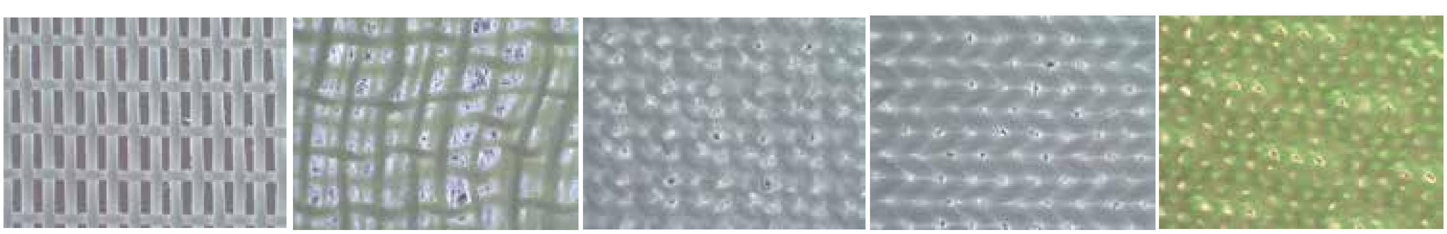

**Mean UPF = 3** **Mean UPF = 9** **Mean UPF = 30** **Mean UPF = 60** **Mean UPF = 115**

**Figure 2: Five examples of real fabrics, all with different amounts of fiber or yarn per unit of surface area and providing different amounts of sun protection. The higher the UPF (ultraviolet protection factor), the greater the protection.**