

# Sunscreens: expectation and realization

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## Summary

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compliance; sunburn; skin cancer; sunscreens

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### Conflicts of interest:

None declared.

**Background:** The technical performance of sunscreens has improved dramatically over the past 20 years, so have we now succeeded in delivering protection that meets consumers' expectations?

**Methods:** From a public health perspective, the desire to prevent sunburn and protect against skin cancer are the two major drivers for using sunscreen. This review examines how well consumers can expect to realize these expectations.

**Results:** Sunscreens are used regularly by a minority of people, even during recreational summer exposure. The failure of sunscreen to prevent sunburn is almost always due to the way that sunscreens are applied rather than technical failure of the product. The mismatch between the labelled protection (sun protection factor) and that delivered in practice is a contributory factor to this 'failure'. Sunscreens have been shown to be effective in reducing the incidence of squamous cell cancer and with promising benefits for basal cell cancer. However, the evidence that they are effective in melanoma remains lacking.

**Conclusion:** The formulation and extinction of sunscreens have undoubtedly improved over recent years. Yet the notion that sunscreens provide unequivocal protection against the deleterious effects of sun exposure by everyone who uses them remains elusive.

In surveys examining people's beliefs about reducing the harmful effects of overexposure to the sun, the measure regarded as being the most important by almost everyone questioned, and across all age groups, was the use of sunscreen (1, 2). So given that sunscreen use is generally regarded as the 'ideal' sun protection measure and there is little question that the technical performance of sunscreens have improved dramatically over the past 20 years, is perception borne out by reality and have we now succeeded in delivering protection that meets consumers' expectations?

## Why do people use sunscreens?

By far the most common reason for using sunscreens, cited by 80% of people surveyed in the United Kingdom in the mid-1990s (3), was to protect against sunburn. Other reasons that people use sunscreens include (4):

- Protect against skin cancer.
- Perceive them at high risk of skin cancer.
- Either previously had skin cancer or know people who have skin cancer.
- Protect against ageing and wrinkling.
- Extend time in the sun.

From a public health perspective, the desire to prevent sunburn and protect against skin cancer are the two major drivers for using sunscreen, so how well can users expect to realize these expectations?

## The sunscreen–sunburn paradox

A paradoxical result of many observational studies is the high prevalence of sunburn in subjects using sunscreen (5–9). So why might this be given that the prevention of sunburn is by far the most common reason for using sunscreens and laboratory testing confirms unequivocally that sunscreens will prevent erythema? The magnitude of sunscreen Sun Protection Factor (SPF) to prevent sunburn can easily be determined given knowledge of the local ultraviolet (UV) climatology, the user's behaviour outdoors and their personal susceptibility to sunburn.

Maximum daily ambient UV levels, expressed in units of Standard Erythema Dose (SED), under clear summer skies are about 70 in the tropics, 60 at mid-latitudes approximating to those of southern Europe, and 40–50 for northern European latitudes (10).

These maximum ambient exposures will not be received by people simply because it would be unrealistic to lie in the

unshaded sun all-day without moving. An extreme sunbather might spend half the time supine and half the time prone, resulting in a maximum exposure on much of the body surface of 50% of ambient. For upright subjects engaging in a variety of outdoor pursuits such as gardening, walking or sport, the exposure relative to ambient on commonly exposed sites, e.g., chest, shoulder, face, forearms and lower legs, ranges from about 20% to 60% (11).

So someone who is on vacation in southern Europe, for example, would receive a daily exposure of no more than 20 SED over much of the body surface, and this equates to about 5–10 MED on the previously unexposed skin of melanocompromised people who do not tolerate the sun well and burn easily (12). Consequently sunscreens need only deliver an SPF of 10 or more to give a sunburn-free vacation. And for tropical sun exposure, an SPF of 15 or higher should be more than adequate to protect against sunburn even for all day exposure.

So then, why do people who use high factor (SPF > 15) sunscreen experience sunburn so frequently? That the protection achieved is often less than that expected is explained by a number of reasons:

- People normally apply much less sunscreen than used in the testing process to determine a product's SPF (13).
- Sunscreen is normally spread haphazardly and not uniformly (14). This applies also to spray-on sunscreens if they are not rubbed in after application (15).
- So-called 'physical' sunscreens containing mineral pigments (TiO<sub>2</sub> or ZnO) can leave a white film on the skin and, as a consequence, people may be encouraged to apply less (16).
- Sunscreens can be removed by water immersion, sand abrasion and towelling (6, 13).
- The timing of sunscreen application influences the protection achieved (17).
- The formulation of the sunscreen can be an important factor influencing an individual's willingness to use and reapply a sunscreen. In a comparative study of formulations including lotions, creams, gels and sprays, an alcohol-based spray formulation of sunscreen was rated the most favourable (18).
- People will tend to apply sunscreen more frequently on those summer days when the weather is fine and they intend spending recreational time outdoors. And it is on days such as these that they are most vulnerable to sunburn if sunscreen application is less than ideal.

All of these factors mean that, as a rule of thumb, the protection achieved is estimated as typically about one third of the rated SPF (13). So in order to achieve 10–15-fold protection, a sunscreen rated SPF30–SPF50 needs to be applied. While there are many more products now offering high (> SPF25) protection today than there were 10 years ago not everybody uses them. In a survey carried out in 2005 of 308 sunscreen products sold in the United Kingdom (19), it was found that while the median SPF was 40 for sunscreens intended for use by babies and children (52 products), the median was only SPF15 for the remaining 256 adult products.

So despite improvements in the UV absorbing properties of sunscreens developed in recent years, we can expect to see disgruntled, sunburnt users claiming their sunscreen did not work for some while to come. Of course, this is more to do with the way sunscreens are used (compliance) than with concerns about their chemical composition or spectral coverage (13, 20).

This mismatch between expected and delivered photoprotection has led many commentators into the trap of believing that consumers use inadequate amounts of sunscreen for protection. The reality is the reverse. People use the quantity they feel comfortable with and in this sense are using the 'correct' amount; it is the labelled SPFs that are misleading. As one study found (21), 78% of the volunteers taking part in a beach study did not like the feeling of sunscreens on their skin and only used them so that they did not sunburn.

So from a public health perspective it is clear that the UV exposure of sunscreen-protected skin depends not just on the absorption characteristics of the product but also on a number of other factors to do with application. A mathematical study (20) that examined the relative importance of three of these factors – amount applied, how it is spread, and UV absorbing properties of sunscreens – found that in a population of sunscreen users most of the variance in UV protection achieved depends upon issues of compliance – how much sunscreen is applied and how well it is applied – with the technical performance of the product (how well it absorbs UV) contributing only about 10% of variance. Consequently the efficacy of a product depends not just on the technical performance of its active UV filters but also on whether the product is pleasing to use.

### Why do people not use sunscreens?

We should not forget that many people do not use sunscreens regularly or at all and the reasons that people give for not choosing to use sunscreens include (4, 18):

- Have skin that does not burn easily.
- Already have 'protective' tan.
- Takes too much time to apply.
- Not outdoors enough to warrant use.
- Nuisance and greasy to apply.
- Feels hot and sweaty.
- Expensive.
- Retards desired tan.
- Use other sun protective measures.
- Forget.

Evidence that the majority of people do not use sunscreen when outside during the summer and that long-term compliance is problematic, is provided from longitudinal studies in Australia examining trends in behavioural risk factors for skin cancer.

The Australian state of Victoria has run a population-based skin cancer prevention programme called SunSmart since 1988, incorporating substantial public education efforts and environmental change strategies. In nine cross-sectional surveys from 1987 to 2002, more than 11 000 adults were interviewed by

telephone about their sun exposure and sun protection during outdoor activities on summer weekends (22). Analyses completed in 2007, adjusted for ambient temperature and UV radiation, showed that use of sunscreens initially increased over time from the baseline summer (1987–1988) when only 12% of respondents claimed to use sunscreen and peaked during the mid–late 1990s when sunscreen was used by one-third of respondents. However, in the most recent survey reported during the summer of 2001–2002, this number had fallen to 27%. So not only do a majority of people claim not to use sunscreen but even some previous users fail to sustain use.

### Is there evidence that sunscreens prevent skin cancer?

Knowledge of the harmful effects of sunlight has increased dramatically in the past two decades, largely due to the combined efforts of public health agencies and the media. People are now much more aware of the risk of skin cancer – the most common human cancer with over 2 million people each year getting skin cancer – from too much sun exposure and will apply sunscreens in the belief that this risk can be reduced by their use. So what evidence is there that sunscreens are effective in this important public health arena?

In April 2000, a Working Group of 23 international experts from Europe, United States, Canada, Australia and Japan convened at the International Agency for Research on Cancer in Lyon to evaluate published data on the cancer-preventive effect of sunscreens. The conclusions of the Working Group were (4)

- Sunscreens probably prevent squamous-cell carcinomas (SCC) of the skin when used mainly during unintentional sun exposure. This conclusion was based almost entirely on the results of a single study (23).
- No conclusion could be drawn about the cancer preventive activity of topical use of sunscreens against basal-cell carcinoma (BCC) and malignant melanoma.
- Use of sunscreens can extend the duration of intentional sun exposure, such as sunbathing. Such an extension may increase the risk for cutaneous melanoma.

### Sunscreen use and prevention of non-melanoma skin cancer (NMSC)

The strongest available evidence that sunscreen use is an effective approach to prevention of NMSC comes from the results of a 4.5-year community-based randomized controlled trial in a subtropical Australian township (23). In comparison with people randomized to using sunscreen at their discretion, if at all, people randomized to daily use of a broad-spectrum SPF15+ sunscreen to their head, neck, arms, and hands at least 3 days each week showed a 40% reduction in SCC tumours at the conclusion of the trial. Eight years after cessation of the 4.5-year sunscreen intervention, participants who had been randomized to daily sunscreen use continued to show a 40% decrease in SCC incidence (24).

Although there was no effect on BCC incidence during the trial period, there was a trend of increasing intervals between BCCs among daily compared with discretionary sunscreen users who developed multiple BCCs (25).

### Sunscreen use and prevention of melanoma

The observation that sunscreens protect against sunburn led to the common expectation that they will also protect against skin cancer, including malignant melanoma. However, it was not until the results of 15 case–control studies were reviewed to evaluate the potential preventive effect of sunscreens against cutaneous melanoma was there some cause for concern (4). Of the 15 studies examined, four provided little evidence of an effect of sunscreen use on the risk of melanoma, three studies showed significantly lower risks for melanoma in sunscreens users compared with non-users, while the remaining eight studies showed significantly higher risks in sunscreen users.

More recently, meta-analyses of observational case–control studies have demonstrated no association between sunscreen use and either the prevention or development of malignant melanoma (26, 27), with failure to control adequately for confounding factors possibly explaining previous reports of a positive association linking melanoma to sunscreen use.

Yet if consideration is given to the period during which the data used in most case–control studies were collected, the UV absorbing properties of sunscreens prevalent at that time, and how sunscreen is used and applied in practice, then the observation that sunscreens appear to play little or no role in preventing melanoma is entirely to be expected as these products probably resulted in an effective SPF of only 2–3 with virtually no protection against wavelengths longer than about 330 nm (28). On the other hand a modern, broad-spectrum sunscreen of SPF25 (typical of popular SPFs) applied at an average thickness of around 1.0 mg/cm<sup>2</sup>, will result in an effective SPF of around 8–10 and a total solar UV radiation (UVA+UVB) dose to the skin of around one-third of that of earlier generation products.

While current evidence of effective prevention of melanoma by sunscreen use remains insufficient, existing data from randomized-controlled trials evaluating sunscreen use that show reduction in solar keratoses (markers of increased risk of melanoma) and decreases in melanocytic nevi (melanoma risk markers/precursors) are not inconsistent with the ultimate preventability of melanoma by broad-spectrum sunscreen (29). It remains to be demonstrated whether modern sunscreens can deliver a clear public health benefit in respect of reducing the risk of melanoma.

### Conclusion

The formulation and extinction of sunscreens have undoubtedly improved over recent years. Yet the notion that sunscreens provide unequivocal protection against the deleterious effects of sun exposure by everyone who uses them remains elusive. Furthermore, sunscreen use during recreational exposure in

periods of high insolation appears to be a behaviour pattern followed by the minority. Future efforts should focus on compliance, rather than technical issues, so that most (if not all) people want to apply sunscreen during high dose-rate sun exposure and as a consequence benefit from the reduced risk of harm that improvements in technology promise to deliver.

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