Sun Protection Factors in Evaluation of Sunscreen Potency: The Persistent Pigment Darkening Method

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The Persistent Pigment Darkening (PPD) method has been modified by Bissonnette et al. [1] as an in vivo assay for UVA exposure. This is the gold standard with which to compare many other methods that assay the potency of sunscreens that block UVA damage. In view of the current interest in evaluation of sun protection factors (SPF), it is important to ensure the validity of current methodology used to evaluate UVB and UVA exposure before meaningful evaluation of sun protection factors and potency of sunscreens against UV-induced damage can be made.

Wavelength specific biological damage has been identified in human skin, with the identification of the sunburn cell [2] in the epidermis with UVB exposure, and changes in the fibroblast [3] in the dermis with UVA exposure, suggesting differences in penetrating properties of the UVB and UVA spectra. The penetrating properties of UVA radiation, capable of penetrating sunscreens and clothing as well as dermal tissues are believed to be mainly responsible for the development of basal cell carcinomas, and malignant melanomas as well as loss of elasticity in photo-aging skin [4], with the less penetrating UVB irradiation responsible for squamous cell carcinomas [4]. Although it is appreciated that the total UVA spectra may be important in causing solar-induced damage [5,6], it is still the erythemal dose of solar exposure that commands the public’s attention because of UVB-induced erythema and burns. However, current knowledge suggests that UBV irradiation may be the less damaging of the two (UVA and UVB). This is due to the fact that UVB irradiation produces Cyclobutane Pyrimidine Dimers (CPDs) that are easily removed and do not produce lasting effects that cause DNA damage. Furthermore, the CPDs produced by UVB irradiation are mainly of the cytosine-thymine, thymine-cytosine and cytosine-cytosine types that are mainly found in cytoplasmic RNA. By contrast, the CPDs generated by UVA radiation are mainly of the thymine-thymine subtypes [7-9] that are found in the DNA, and are more genotoxic and correlate with the mutation spectrum [7-9]. In addition, UVA produce CPDs that result in damage to large segments of the DNA, as well as damage to both strands of the DNA, which are more difficult to repair and, therefore, more mutagenic [10]. Although UVA appears to be the more mutagenic of the two, it is likely that since CPDs are formed by wavelengths of both spectra, which the synergistic combination of the entire UV spectrum may account for the total carcinogenic potential seen with solar irradiation.

Sunscreens have been developed to protect against UV damage, with their potency assessed in terms of sun protection factors or SPF. Since the erythema and burning properties of solar irradiation lies mainly in the UVB spectra, it is relatively easy to assess the effectiveness of sunscreens in protecting against the erythemal doses of UVB, and the ensuing inflammatory response [11] due to UVB-induced injury. However, with the observation that the inflammatory doses of UV exposure, which are mainly in the UVB spectrum, have been observed not to be necessary for carcinogenesis [11] together with identification of the UVA spectrum as the mutagenic spectrum [7-10] attention has been focused on the development of sunscreens which can block UVA as well as UVB i.e., the so-called broad-spectrum sunscreen. Since UVA is a silent invader which produces little erythema or burning, the usual methods for assessing protection from UVB exposure are not adequate for assessing UVA exposure. The inadequacy of current sunscreens to protect against UVA-induced injury is suggested by the rising trends of cutaneous melanoma reported in several countries [12-15].

The validity of current assays for UV exposure is called into question when these assays show adequacy of sun protection which cannot be correlated clinically. Such may be the case with the Persistent Pigment Darkening assay described by Bissonnette et al. [1].

Immediate pigment darkening (IPD), was originally thought to be achieved by UVA, but may also be induced by wavelengths of the UVB spectra, and is a measure of conversion of colorless melanin to colored melanin. This occurs minutes after UVA exposure, and lasts less than 2 hours. The pigmentation is evanescent and unreliable, as it differs greatly in individuals of different capacities to produce pigmentation. Persistent pigment darkening (PPD) is thought to be induced by wavelengths of 290 – 320 nm or UVB range, but may also be induced by wavelengths of the UVA spectra, since UVA irradiation is the predominant wavelength from solar exposure reaching the melanocytes at the dermoepidermal junction. The process of persistent pigment darkening which persists for several days to weeks involves protein synthesis of new melanin molecules. This takes place at least 18-24 hours after UV exposure, since protein synthesis requires at least 18-24 hours. The newly synthesized melanin pigment lasts at least 3 weeks after UV exposure – hence the term persistent pigment darkening. On the other hand, the colored melanin generated by the IPD response, reverts back to the colorless form by a reversible reaction usually within hours of UV exposure.

The PPD method has the advantage of being an in vivo method. However, the current method used to assess persistent pigment darkening [1] assesses increased pigmentation by a colorimetric and visual technique at 2 hours after exposure to solar-simulated UVA light, using a xenon arc lamp with appropriate filters. The increase in pigmentation two hours following solar simulated UVA is almost certainly not due to melanin protein synthesis, which requires at least 18-24 hours following UV exposure. It must be noted that increased pigmentation at 24 hours or more include new melanin synthesis,

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Other methods of evaluating UVA protection, including quantification of p53 protein to evaluate level of UVA protection [16,17] and quantification of cyclobutane pyrimidine dimers (CPDs), [8-17] with newer methods such as diffuse reflectance spectroscopy [18] and even Immediate Pigment Darkening [19] have been reported to be useful in evaluating UVA radiation damage. However, their validity and clinical correlation have yet to be determined.

References
8. Hwang YJ, Park HJ, Hahn HJ, Ko JH, et al. (2011) Immediate pigmentation should be evaluated 2-3 days following after UVB and UVA exposure, which is not done in current assessments of persistent pigment darkening methods.

plus residual colored melanin converted from colorless melanin. To strictly assess the effect of persistent pigment darkening (i.e., UVB and UVA exposure), the pigmentation should be evaluated 2-3 days following after UVB and UVA exposure, which is not done in current assessments of persistent pigment darkening methods.

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References
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