Comparison of UVA protection afforded by high sun protection factor sunscreens

Robert Bissonnette, MD, MSc, FRCPC,[a] Soraya Allas, MD, PhD,[a] Dominique Moyal, PhD,[b] and Nathalie Provost, MD, FRCPC[a] *Montreal, Québec, Canada, and Clichy, France*

UVA protection afforded by 6 different sunscreens with a sun protection factor of 21 or more was compared by means of the persistent pigmentation darkening method. Colorimetric and visual assessment showed significant differences in UV radiation–induced pigmentation at 2 hours. The labeled sun protection factor of the tested sunscreens was not predictive of UVA protection level. (J Am Acad Dermatol 2000;43:1036-8.)

Ultraviolet A (UVA, 320-400 nm) makes up the major portion of ultraviolet radiation reaching the surface of the earth. UVA has been shown to play a role in skin carcinogenesis, photodermatosis induction, and other sun-induced skin diseases. It can induce mutations in cultured cells[1] as well as squamous cell carcinoma in hairless mice.[2] UVA has been recognized to be involved in the genesis of solar elastosis[3] and is the major waveband responsible for polymorphous light eruption, the most common of the idiopathic photodermatoses.[4] It is therefore relevant to be able to evaluate UVA protection afforded by sunscreens. The sun protection factor (SPF) is a simple and internationally used method to compare sunscreen protection against UV erythema, which is predominantly induced by UVB. The SPF can be used as a guide to select a sunscreen to avoid sunburn. However, there is no universally accepted method to evaluate UVA protection afforded by sunscreens. UVB/UVA-labeled sunscreens are thus sold with no indication of the level of UVA protection they provide. In this study we used the pigmentation darkening method to compare UVA protection afforded by 6 commercially available sunscreens with an SPF of 20 or more that claimed on their label to offer UVA and UVB protection.

From the Division of Dermatology, University of Montreal Hospital Centre, Montreal,[a] and L'Oréal Research, Clichy.[b]

Supported by a grant from La Roche-Posay Pharmaceutical Laboratories.

Accepted for publication May 24, 2000.

Reprint requests: Robert Bissonnette, MD, MSc, FRCPC, Division of Dermatology, University of Montreal Hospital Centre, Notre-Dame Hospital, 1560 Sherbrooke St East, Montreal, Quebec, Canada H2L 4M1. E-mail: rbissonn@globetrotter.qc.ca.

0190-9622/2000/$12.00 + 0 **16/1/109299**

doi:10.1067/mjd.2000.109299

METHODS

After ethics board approval, informed consent was obtained from 12 volunteers with skin phototype III or IV and with no history of sun or artificial light exposure on their back for at least 3 months. Volunteers who were taking photosensitizing medication or who had a history of lupus, porphyria, or another light-sensitive dermatosis were excluded. Six commercially available sunscreens with an SPF of 21 or higher were studied (Table I). Sunscreens were selected among frequently used brands to include 2 sunscreens with physical agents only, 2 sunscreens with at least Parsol 1789 as a chemical agent for UVA protection, and 2 sunscreens with chemical agents but without Parsol 1789 and Mexoryl SX. Three of the 6 sunscreens were applied at a rate of 2 mg/cm^2 on the back of each volunteer in a double-blind fashion so that each sunscreen was applied on exactly 6 volunteers. After 15 minutes the back of each volunteer was exposed to UV light generated by a metal halide lamp (UVA spot 400/T, Dr K Hönle UV-Technologie, Munich, Germany). For each sunscreen, five 1.5 × 1.5 cm squares of normal skin on the back were exposed to one of the following UVA doses: 20, 29, 44, 67, and 100 J/cm^2. The ultraviolet spectral output of this source includes both UVA and UVB (290-400 nm) and is similar to the spectral output of the sun (Fig 1). Irradiance was measured with a radiometer (Centra Osram, Berlin, Germany) equipped with UVA and UVB detectors and was 20 mW/cm^2 for UVA and 0.55 mW/cm^2 for UVB. Two hours after UV exposure, the pigmentation of the exposed sites was compared visually with adjacent normal skin and graded on a scale of 0 to 4, where 0 meant no difference from adjacent skin and 4 meant marked pigmentation. Pigmentation intensity was also measured with a colorimeter (Minolta CR200) in the L*a*b mode. Measurements were taken in tripli-

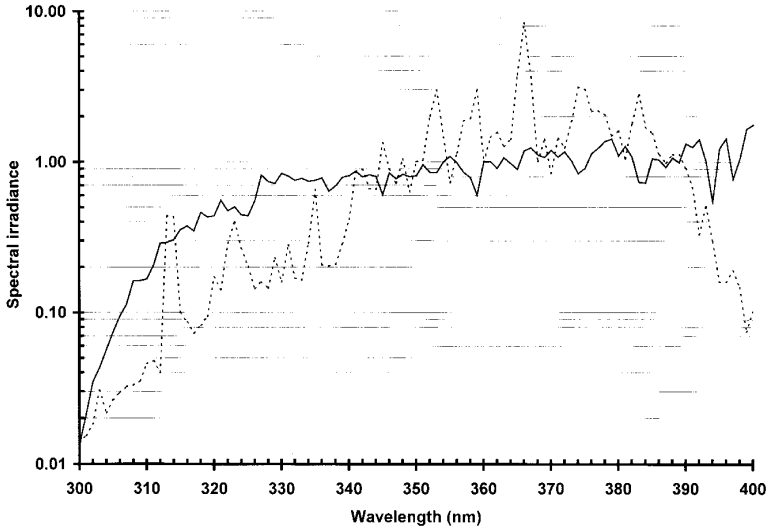

Fig 1. Spectral irradiance of the metal halide lamp used in this study (*dotted line*) as measured with a spectroradiometer (model SR3010-PC, Macam Photometrics, Livingston, UK) and compared with a zenithal standard sun spectrum (DIN 67501) (*solid line*).

cate from each exposed site as well as from adjacent normal skin. The pigmentation intensity of each square was calculated by subtracting the mean L (luminance) value of the square by the mean L value of adjacent skin. Mean pigmentation for both the visual and colorimetric method was calculated for each sunscreen at each of the 5 UVA exposure intensity and compared using an analysis of variance for repeated measures method.

RESULTS

Two hours after exposure, intense pigmentation could be seen on some of the sites exposed to UV radiation. For visual assessment differences were observed between the various sunscreens at 20 J/cm^2, but they were not statistically significant (Fig 2, *A*). At a dose of 100 J/cm^2, pigmentation intensity was lowest for sunscreen A, followed in order of increasing pigmentation by sunscreens D, F, E, C, and B (Fig 2, *A*). The difference in visual pigmentation between sunscreen A and all other sunscreens at 100 J/cm^2 was statistically significant ($P < .001$). For colorimetric analysis the pigmentation was lowest for sunscreen A followed in order of increasing pigmentation by sunscreens D, F, E, C, and B (Fig 2, *B*). The difference in pigmentation intensity at 100 J/cm^2 between sunscreen A and all other sunscreens, as measured with the colorimeter, was statistically significant ($P < .017$) except for sunscreen D.

DISCUSSION

Several techniques have been used to compare UVA protection afforded by sunscreens including assess-

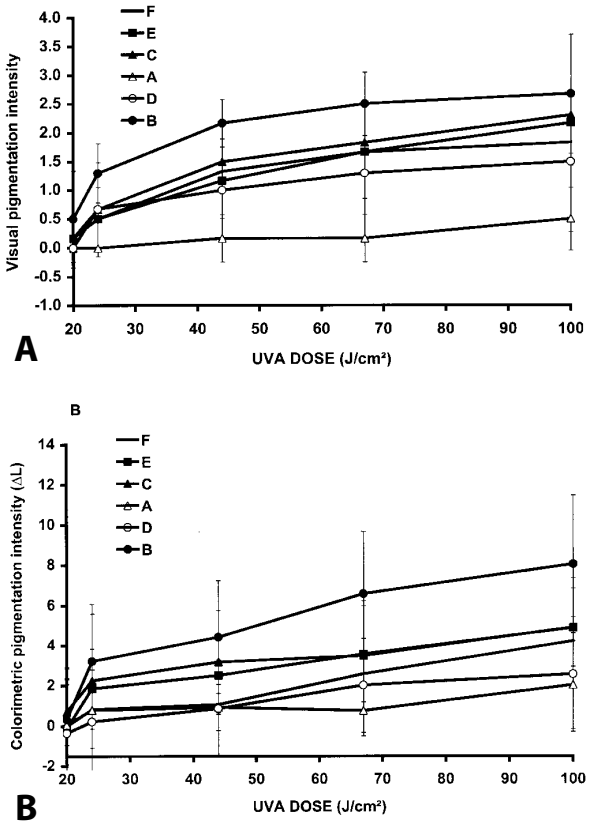

Fig 2. Pigmentation intensity according to UVA doses assessed with the visual **(A)** and colorimetric **(B)** method 2 hours after exposure to UV radiation. For colorimetric measurements the luminance *(L)* of the UV-exposed skin was subtracted from the luminance of the adjacent covered skin.

Table I. Active sunscreening agents of sunscreens studied

Sunscreen	Chemical agent	Physical agent
A	Mexoryl SX 3.3% 4-Methylbenzylidene camphor 5.0% Parsol 1789 (butylmethoxydibenzoylmethane) 3.5%	Titanium dioxide 4.1%
B	Octyl methoxycinnamate 7.5% Octyl salicylate 5.0%	Titanium dioxide
C	Homosalate 8.0% Ethythexyl *p*-methoxycinnamate 7.5% Oxybenzone 6.0% Octyl salicylate 5.0%	
D	Parsol 1789 (butyl methoxydibenzoylmethane) 3.0% Octyl methoxycinnamate 7.5% Octyl salicylate 5.0% Oxybenzone 3.0%	
E	—	Titanium dioxide 9.6% Zinc oxide 1.5%
F	—	Titanium dioxide 12.0%

ment of immediate pigmentation darkening (IPD),[5] persistent pigmentation darkening (PPD) at 2 to 24 hours,[6] UVA-induced erythema,[7] erythema induced after topical psoralens application and UVA exposure,[8] and in vitro spectroscopic methods.[9] The action spectrum of PPD is maximum at short UVA wavelengths and gradually decreases from 320 to 400 nm.[10,11] PPD response has been shown not to be influenced by UVA irradiance, as opposed to IPD response, suggesting that PPD may be a better method to compare UVA protection afforded by sunscreens.[10] At 100 J/cm^2, the maximal UVA dose applied in this study, photostability was indirectly studied with the PPD method, as photodegradation of sunscreens occurs after only 18 J/cm^2 of UV exposure.[9]

Sunscreen A, which induced the lowest pigmentation intensity, contained Parsol 1789, Mexoryl SX, and titanium dioxide for UVA protection. The second best, sunscreen D, was the only other sunscreen with Parsol 1789 and was followed by the 2 physical sunscreens and the 2 sunscreens with only benzophenones for UVA protection. The sunscreens that protected the least against UVA-induced pigmentation were the sunscreens with the second and third highest SPF (45 and 50), showing that selecting a high SPF sunscreen cannot be used as the only guide to compare UVA protection afforded by sunscreens. Although the visual and colorimetric assessments rated UVA pigmentation of the 6 tested sunscreens in the same order, there were differences in the shape of the pigmentation curves for a given sunscreen. These differences and the negative values observed at 20 J/cm^2 with colorimetry could be related to the precision limit of the technique as well as the difficulty of performing colorimetric measurements on a small skin area with our colorimeter.

In conclusion, labeled SPF is not predictive of UVA protection as assessed by pigmentation induced at 2 hours after exposure to UV radiation. In addition to SPF, another labeling method to specifically compare UVA protection could help in sunscreen selection.

REFERENCES

1. Drobetsky EA, Turcotte J, Chateauneuf A. A role for ultraviolet A in solar mutagenesis. Proc Natl Acad Sci 1995;92:2350-4.
2. de Gruijl FR, Sterenborg HJ, Forbes PD, Davies RE, Cole C, Kelfkens G, et al. Wavelength dependence of skin cancer induction by ultraviolet irradiation of albino hairless mice. Cancer Res 1993;53:53-60.
3. Fourtanier A, Labat-Robert J, Kern P, Berrebi C, Gracia AM, Boyer B. In vivo evaluation of photoprotection against chronic ultraviolet-A irradiation by a new sunscreen Mexoryl SX. Photochem Photobiol 1992;55:549-60.
4. Neumann RA, Pohl-Markl H, Knobler RM. Polymorphous light eruption: experimental reproduction of skin lesions by whole-body UVA irradiation. Photodermatology 1987;4:252-6.
5. Kaidbey KH, Barnes A. Determination of UVA protection factors by means of immediate pigment darkening in normal skin. J Am Acad Dermatol 1991;25:262-6.
6. Roelandts R, Sohrabvand N, Garmyn M. Evaluating the UVA protection of sunscreens. J Am Acad Dermatol 1989;21:56-62.
7. Cole C, VanFossen R. Measurement of sunscreen UVA protection: an unsensitized human model. J Am Acad Dermatol 1992; 26:178-84.
8. Lowe NJ, Dromgoole SH, Sefton J, Bourget T, Weingarten D. Indoor and outdoor efficacy testing of a broad-spectrum sunscreen against ultraviolet A radiation in psoralen-sensitized subjects. J Am Acad Dermatol 1987;17:224-30.
9. Diffey BL SR, Forestier S, Mazilier C, Rougier A. Suncare product photostability: a key parameter for a more realistic in vitro efficacy evaluation. Part I: in vitro efficacy assessment. Eur J Dermatol 1997;7:226-8.
10. Chardon A, Moyal D, Hourseau C. Persistent pigment darkening response as a method for evaluation of UVA protection assays. In: Lowe NJ, Shaath N, Pathak M, editors. Sunscreens: development, evaluation and regulatory aspects. New York: Marcel Dekker; 1994. p. 559-82.
11. Irwin C, Barnes A, Veres D, Kaidbey K. An ultraviolet radiation action spectrum for immediate pigment darkening. Photochem Photobiol 1993;57:504-7.