Protection from visible light by commonly used textiles is not predicted by ultraviolet protection

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Interest is increasing in the prevention of acute and chronic actinic damage provided by clothing. This interest has focused mainly on protection against ultraviolet irradiation, but it has now also turned to protection against visible light. This change is mainly due to the action spectrum in the visible light range of some photodermatoses and the increasing interest in photodynamic therapy. The ultraviolet protection provided by commercially available textiles can be graded by determining an ultraviolet protection factor. Several methods have already been used to determine the ultraviolet protection factor. The fact that protection from visible light by textiles cannot be predicted by their ultraviolet protection makes the situation more complicated. This study attempts to determine whether or not the ultraviolet protection factor value of a particular textile is a good parameter for gauging its protection in the visible light range and concludes that a protection factor of textile materials against visible light needs to be developed. This development should go beyond the protection factor definition used in this article, which has some limitations, and should take into account the exact action spectrum for which the protection is needed. (J Am Acad Dermatol 2006;54:86-93.)

The prevention of actinic damage has become increasingly important in recent years. The change in sun exposure habits over the past few decades has increased the incidence of a variety of photodermatoses, skin aging, and skin cancer. Not only is the incidence of skin cancer increasing, but the age at which first symptoms appear is decreasing, which is even more frightening. Because of the long interval between the sun exposure and the development of skin cancer, a higher increase may be expected in the future. Therefore adequate sun protection is becoming even more necessary.

Up to quite recently, sun protection was considered mainly a matter of use of sunscreens. However, the use of broad-spectrum sunscreens with high sun protection factor (SPF) values often resulted in people exposing their skin much longer to the damaging effects of sun exposure, the precise opposite of the intended effect.[1] Therefore sun protection by textiles has become more and more important because it can provide better protection than sunscreens. Clothing fabrics have been proposed in the treatment of photosensitive patients[2,3] as well as for protection against xeroderma pigmentosum[4] and premalignant lesions.[5,6]

Abbreviations used:

ALA:	aminolevulinic acid
SPF:	sun protection factor
UPF:	ultraviolet protection factor
UV:	ultraviolet
VPF:	protection factor for visible light

Clothing can be labeled with a protection factor in the ultraviolet (UV) range (ultraviolet protection factor; UPF),[7,8] in the same way as the SPF for sunscreens. Different methods have been used.[2-5,7,9-11] Commercial summer fabrics, however, frequently provide insufficient UV protection.[12]

Labeling is already available in Australia, New Zealand, Europe, the United States, and Canada, although this may vary from one country to another. In Australia, the measured UPF is marked if the UPF is between 15 and 50.[13] In the United States, the test method for determining the UPF was developed by the American Association of Textile Chemists and Colorists.[14] The classification and labeling of clothing follows the Australian classification system.[15] In

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Europe, clothing can bear a "UV-protective" label only if the UPF is higher than 40 and if, at the same time, UVA transmission is less than 5%. A UPF of 40+ seems to be sufficient even in extreme exposure situations.[16] The European standard further specifies clothing design requirements such that as much skin as possible is covered.[17,18]

In general, in vivo methods (eg, erythema-response methods) produce lower UPF values than do in vitro methods (eg, transmission measurements).[11,19,20] Not only the method used but also environmental factors such as wetness may increase or decrease the UPF depending on the fabric.[19,21,22] Indeed, even everyday use may improve the UPF of pure cotton, at least in the short term.[23] The addition of UV absorbers, optical brightening agents, and dyes may also alter the degree of protection. In the meantime, industry is increasing the research into UV protective textiles in the effort to improve this protection. There is also a growing awareness on the part of consumer organizations.

Textiles offer protection against visible light, a spectrum for which sunscreens offer much less protection than for UV light. Some photosensitive patients have an action spectrum in the visible light range. In addition, visible light sources are used for photodynamic therapy for precancerous lesions or superficial skin cancers, so it may also be wise to protect the skin against visible light. When protection in the visible light range becomes important, this protection needs to be evaluated. Only a few such studies have been done.[24]

The purpose of this study is to evaluate the protection of textile materials against visible light and to determine whether the UPF used to grade the protection in the UV range is also a valid parameter for the classification of protection in the visible light range.

MATERIAL AND METHODS

Fabrics

Thirty-four different textiles, suitable for summer clothing, were evaluated for the protection they provided against visible light after a UPF had been determined for each of them.

The series contains cellulosic materials (eg, cotton, viscose, flax) and synthetic materials of various kinds (eg, acrylic, polyester, polypropylene). The materials, either woven or knitted, were all plain materials. The composition, color, density, and structure of the materials are given in Table I.

Determination of the UPF

The UPF was determined according to the European Committee for Standardization Norm EN13758-1 using the following formula[17]:

$$\mathrm{UPF} = \frac{\sum_{290}^{400} E(\lambda)S(\lambda)\Delta(\lambda)}{\sum_{290}^{400} E(\lambda)S(\lambda)T(\lambda)\Delta(\lambda)}$$

where $E(\lambda)$ is the irradiance of the sun expressed in watts per nanometer per square meter; $S(\lambda)$ is erythema action spectrum; $\Delta(\lambda)$ is the bandwidth; and $T(\lambda)$ is the transmission coefficient of the material, as determined by the relation between the intensity of the transmitted radiation to the intensity of the incident radiation. Since $S(\lambda)$, $E(\lambda)$, and $\Delta(\lambda)$ are known, the UPF can be calculated by means of the transmission coefficient $T(\lambda)$. The transmission percentage of the radiation was measured with a spectrometer. Normal incident monochromatic radiation was used in combination with collection of radiation from an integrating sphere (UV/VIS/NIR PerkinElmer Lambda 900; PerkinElmer, Boston, Mass) to measure direct and diffuse radiation simultaneously. A UG11 Schott filter of 2-mm thickness (Schott, Mainz, Germany) was used between the sample and the integrating sphere to minimize the fluorescence that could be induced by the optical brightening agents. Fluorescence emission could increase the transmission and thus lead to underestimating the UPF.

Approximately 90% of all white materials contain optical brightening agents, which have fluorescent characteristics. They absorb radiation around 350 to 360 nm and re-emit these rays at higher wavelengths, namely 400 to 430 nm. With this absorption, they have a favorable effect on the UPF.

Determination of the visible-light protection factor

To determine the protection factor of the textile materials at a particular wavelength in the visible light range, two methods were used. In the first method a 900-W xenon lamp was used in combination with a monochromator (Applied Photophysics, London, UK). The transmission was measured at different wavelengths in the visible light range: 400, 450, 500, 550, 600, 650, and 700 nm. The bandwidth for each of these wavelengths was 32 nm. The intensity was measured with a thermopile. The transmission was determined by comparing the intensity at each wavelength through the textile sample and without the textile sample (the control).

The second method used a spectrophotometer equipped with an integrating sphere. The light generated by a xenon source passes through a monochromator with a bandwidth of 1 nm and impinges perpendicular to the sample. The sample is positioned in front of the integrating sphere for collection