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Photoprotective Ability of Sunscreens against Ultraviolet, Visible Light and Near-Infrared Radiation

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Abstract

Despite the widespread prevalence of daily sunscreen usage, solar-induced skin damage continues to occur. We have previously reported that solar visible light and near-infrared, in addition to ultraviolet radiation, perform as aging factors and induce deleterious effects such as photoaging, vasodilation, muscle thinning, skin ptosis, photoimmunosupression and photocarcinogenesis. Despite this, most commonly used sunscreens only block ultraviolet radiation. To evaluate the complete solar-spectrum blocking ability of sunscreens produced by internationally well-known companies, a double-beam spectrophotometer was used to optically measure the transmission spectra. The spectrophotometer utilizes a unique, single monochromatic design covering a wavelength range of 240 to 2600 nm. Sunscreens (thickness, 0.1 mm, SPF50+, PA+++ or ++++) from internationally well-known companies blocked 78.8% - 99.9% of ultraviolet, 33.4% - 99.6% of visible light, and 27.0% - 76.4% of near-infrared. It can be concluded that while most commercially available sunscreens filter ultraviolet radiation, they are not effective at blocking visible light and near-infrared radiation. The results of this study imply that sunscreens that provide comprehensive photoprotection from ultraviolet through to near-infrared should be considered to prevent skin photodamage.

Keywords

Anti-Photoageing, Photoprotection, Sunscreen, Ultraviolet, Visible Light, Near-Infrared

1. Introduction

Despite the wide prevalence of a variety of ultraviolet (UV) blocking materials,

such as sunscreens, eyewear, glass film treatments, umbrellas, and fibers, visible light and near-infrared (NIR) are not effectively blocked and the deleterious biological effects of visible light and near-infrared have not been well recognized [1]-[11]. We previously reported that NIR can penetrate skin and sclera and affect the deeper tissues, including muscles, lens, and retina. Such high permeability results in NIR induce considerable and varied biological effects [3] [4] [6]. Continual long-term exposure to NIR can induce various kinds of tissue damage and diseases, such as undesirable photoaging [1]-[7] [11], long-lasting vasodilation [9], muscle thinning [10], sagging and skin ptosis [1] [2] [3] [4], photoimmunosuppression, and photocarcinogenesis, when biological protection against the relevant electromagnetic spectral radiation is not achieved [1]-[13].

As human skin is exposed to significant amounts of electromagnetic spectral radiation [1]-[11] [14] [15], and most solar filtering materials cannot block visible light (VL) and NIR, consideration should be given to developing and deploying photo-protective materials against VL and NIR also [1] [11].

To clarify the complete solar-spectrum blocking ability of common commercially available sunscreens (SPF50+, PA+++ or ++++) produced by internationally well-known companies, a double-beam spectrophotometer was used to optically measure the transmission spectra from 240 to 2600 nm.

2. Materials and Methods

2.1. Sunscreens Evaluated

Nine commonly commercially available sunscreens with SPF50+, PA+++ or PA++++ ratings from internationally well-known companies were used in this study. Three from American (US) companies, two from Australian (AU) companies and four from Japanese (JP) manufacturers.

2.2. Optical Evaluation of Sunscreens Using Transmission Spectra

To evaluate commercially available sunscreens produced by internationally well-known companies, a double-beam spectrophotometer was used to optically measure the transmission spectra.

Each sunscreen sample was embedded in sapphire cuvette with a thickness of 0.1 mm, simulating practical use of human skin. The spectrophotometer utilizes a unique, single monochromatic design covering a wavelength range of 240 to 2600 nm. The emitted light was detected by a photomultiplier tube.

3. Results

Blocking ability against UVC, UVB, UVA, VL, and NIR of each sunscreen sample (SPF50+, PA+++ or ++++, with a thickness of 0.1 mm) is shown in **Table 1**. The results of the transmission spectra of sunscreens with a thickness of 0.1 mm are shown in **Figure 1**.

All sunscreens evaluated blocked 99.4% - 99.8% of UV-C (100 - 280 nm), 98.8% - 99.8% of UV-B (280 - 315 nm), 78.8% - 99.9% of UV-A (315 - 400 nm),

Table 1. Blocking abilities of sunscreens.

	Blocking abilities				
	UV-C	UV-B	UV-A	VL	NIR
Sample No. 1 from US	99.5% - 99.7%	99.7%	94.0% - 99.9%	73.1% - 94.0%	66.1% - 73.1%
Sample No. 2 from US	99.4% - 99.5%	99.4% - 99.5%	80.0% - 99.8%	29.1% - 80.0%	27.0% - 29.1%
Sample No. 3 from US	99.4% - 99.5%	99.5%	80.0% - 99.9%	61.3% - 80.0%	52.0% - 61.3%
Sample No. 4 from AU	99.5% - 99.7%	99.7%	99.6% - 99.9%	71.2% - 99.6%	65.9% - 71.2%
Sample No. 5 from AU	99.7% - 99.8%	99.8%	98.5% - 99.9%	76.4% - 98.5%	65.3% - 76.4%
Sample No. 6 from JP	99.6% - 99.7%	99.7%	96.8% - 99.9%	57.7% - 96.8%	46.0% - 57.7%
Sample No. 7 from JP	99.4% - 99.5%	98.8% - 99.5%	78.8% - 98.8%	33.4% - 78.8%	34.3% - 33.4%
Sample No. 8 from JP	99.5% - 99.7%	99.7%	79.4% - 99.8%	56.2% - 79.4%	35.8% - 56.2%
Sample No. 9 from JP	99.4% - 99.5%	99.5%	85.7% - 99.9%	69.7% - 85.7%	50.6% - 69.7%

29.1% - 99.6% of VL (400 - 760 nm), and 27.0% - 76.4% of NIR.

All commercially available sunscreens blocked UVC and UVB sufficiently (approximately 99%), but only 1 sample blocked over 99% of UVA. None of the sunscreens was able to block VL and NIR sufficiently (Table 1).

Transmission spectra showed that all commercially available sunscreens blocked UVC and UVB sufficiently, but many samples did not block UVA effectively. None of the sunscreens were able to sufficiently block VL and NIR (Figure 1).

4. Discussion

Biological effects of sun and UV exposure have been extensively investigated. Exposure to UV radiation is the most important environmental carcinogen [16] and plays a significant role in the development of melanoma [17]. Sunscreens reduce the effects of UV radiation on human skin [18] [19] [20]. Nevertheless, sunscreens have failed to protect against an increase in UV radiation-induced melanomas [17].

Various kinds of UV blocking materials, such as sunscreens, films, paints, and fibers are often used to prevent skin damage from UV exposure. Most sunscreens can only block UV and not visible light or near-infrared (NIR) radiation.

Incident solar energy comprises less than 10% UV, approximately 40% VL, and over 50% NIR. Despite widespread sunscreen use globally, motivated by the desire to prevent skin damage, skin cancer and photoageing continue to pose a health threat worldwide.

Over 90% of solar radiation affecting the Earth consists of VL and NIR, and intensive or ongoing exposure to VL and NIR, when combined with UV, also contributes to skin cancer and photoageing [11]. It must be noted that the global sunscreen industry has not embraced effective formulation technologies designed to filter VL and NIR [11]. As the biological effects of solar energy (UV,

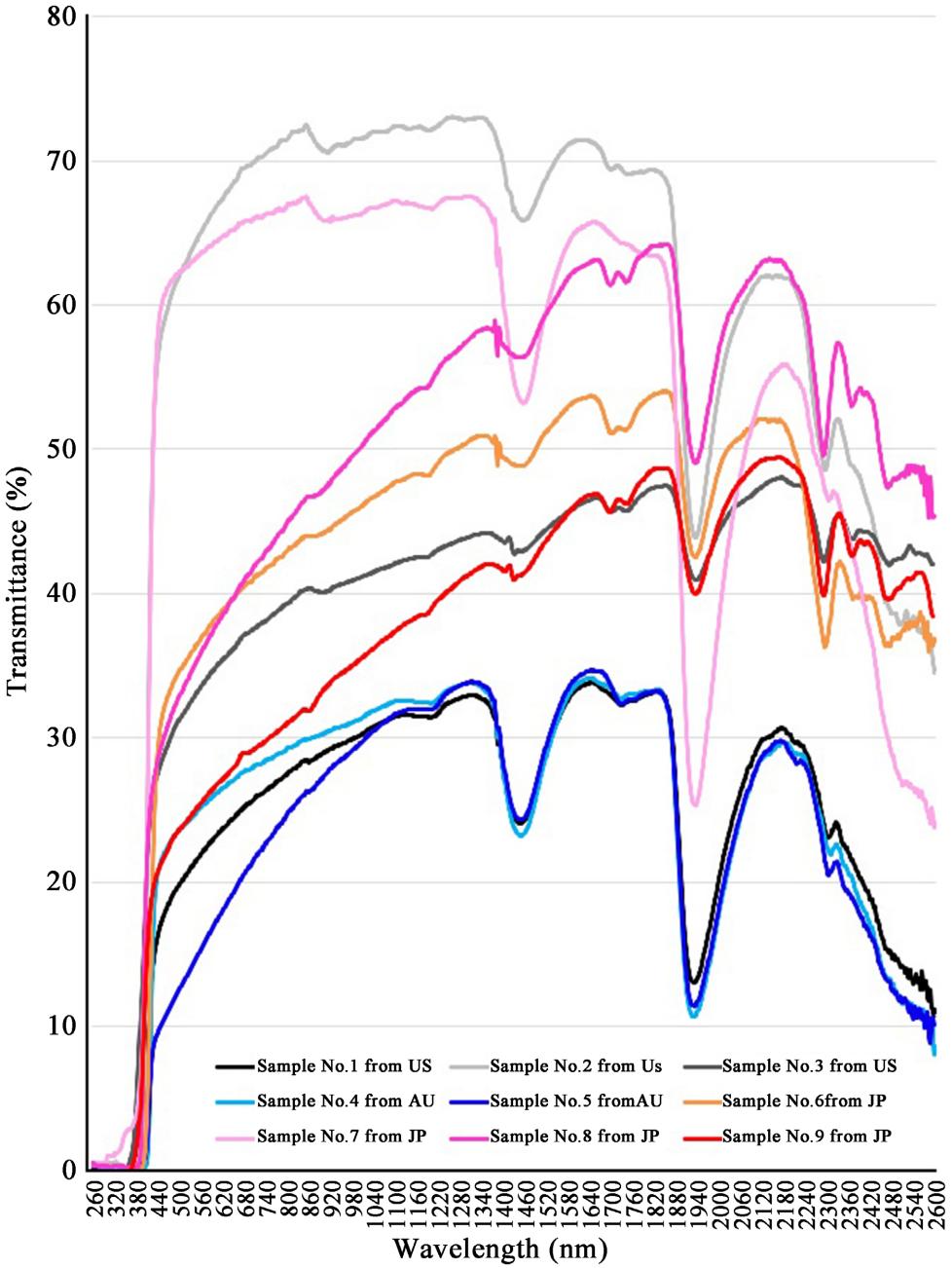

Figure 1. Optical evaluation of sunscreens using transmission spectra.

VL and NIR) are significant, solar protection from UV, VL and NIR is effective in preventing photoageing [11].

NIR performs as an aging factor, where biological NIR protection is not complete [1]-[11]. NIR induces photoaging similar to that observed in solar elastosis, and enhances UV-induced dermal damage [21]. Long-term exposure of NIR from various heat sources, such as fires and stoves, results in *erythema ab igne* [22], and results in histopathological changes similar to those seen in solar-damaged skin [23]. The occurrence of telangiectasia and pigmentation appears to increase with age and increased sun exposure [24].

NIR induces various kinds of tissue damage and diseases, such as undesirable photoaging, long-lasting vasodilation, muscle thinning, skin ptosis, sagging, cataracts, and potentially photocarcinogenesis. In addition, skin tumors appeared faster after irradiation with exposure to solar simulations containing UV, VL, and NIR compared to irradiation with UV alone [25].

In this study, all of the commercially available sunscreens evaluated blocked UVC and UVB sufficiently (approximately 99%). Although the deleterious biological effects of the entire UV spectrum are well known and many studies have recommended increased protection against UVA, 8 of the 9 samples evaluated here were not able to block over 99% of UVA.

None of the evaluated sunscreens effectively blocked VL and NIR, and this could potentially explain increasing levels solar-induced skin damage being reported despite the widespread prevalence of sunscreen usage.

Interestingly, SPF and PA appeared to be uncorrelated with the optical evaluation results in this study, which may suggest that SPF and PA are the clinical criteria evaluated by volunteers' skin reaction and the values depend on the volunteers' skin type. While SPF50+, PA+++ or PA++++ rated sunscreens are believed to be very effective in the prevention of photoageing, they only block UV, and not VL or NIR sufficiently. Samples evaluated in this study with a thickness of 0.1 mm appears to be quite thick compared with daily consumer application dosage of sunscreens.

These results reinforce that commercially available sunscreens are still not optimal for anti-photoageing and photoprotection against VL and NIR.

It should be noted that this was a preliminary study based on a relatively small number of sunscreen samples. Further studies are needed in larger numbers and various types of sunscreens and in investigation of biological effects of VL and NIR.

5. Conclusion

Many commercially available and popular sunscreens are rated SPF50+. PA+++ or PA++++, thought to be useful for anti-photoageing and anti-carcinogenesis, blocks a wide range of UV, but offers limited protection against UVA, VL and NIR radiation. The results of this study indicate that sunscreens that provide comprehensive photoprotection from UV through to NIR should be considered for comprehensive skin protection from solar damage.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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