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Assessment of photoprotection against pigmentation induced by visible light using a new *in vitro* method: correlation and new *in vivo* photoprotection factor against visible light

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INTRODUCTION

While UV radiation is the main cause of skin pigmentation, visible light (400-700 nm) has been shown to be a major contributor, in particular in melanocompetent subjects. The fact that photoprotection against visible light, in particular blue light, improves a number of hyperpigmentation disorders has led to the development of sunscreens containing specific pigments that block blue light (iron oxides and titanium dioxide). To assess the efficacy of sunscreens on visible light photoprotection, an assessment method has recently been suggested by Lim *et al.* based on *in vivo* pigmentation, leading to the calculation of the visible light photoprotection factor (VL-PF)[1,2]. This involves measuring changes in the ITA° colorimetric parameter over several days using a chromameter[2]. However, although *in vivo* methods are still the most representative of real life, *in vitro* methods are better suited to screening suncare formulations. The purpose of our study was to assess the correlation between *in vivo* and *in vitro* methods in assessing protection against visible light-induced pigmentation.

MATERIALS AND METHODS

Initially, the *in vitro* photoprotective properties of 10 sunscreens (9 of which contained pigments) offering very high photoprotection (≥SPF50+) were analysed using transmission measurements in the visible spectrum. Next, a single-centre, double-blind, randomised controlled study with intra-individual comparisons on 20 healthy subjects was carried out to measure the *in vivo* VL-PF of these sunscreens. This VL-PF was reinterpreted as a percentage using the (1-(1/VL-PF))×100 formula and named pVL-PF (0% corresponding with an untreated exposed area and 100% with full theoretical protection against visible light, equivalent to an unexposed area). The correlation between pVL-PF and the percentage of blocked light was assessed using the coefficient of determination R, for each test area, for each wavelength from 400 to 700 nm and for each wavelength range from 400 nm. Statistical analysis was carried out using Pearson correlation.

RESULTS

In vitro, the transmission spectra of tinted sunscreens showed that the best protection was achieved in high-energy visible light **(Fig 1a)**. *In vivo*, twenty subjects (13 women and 7 men) with an average age of 34.9 (18 to 49) were included in the study. The pVL-PF obtained ranged from 9.7% (for the non-tinted sunscreen) to 66.4% (for one of the tinted sunscreens) **(Fig. 1b-c)**.

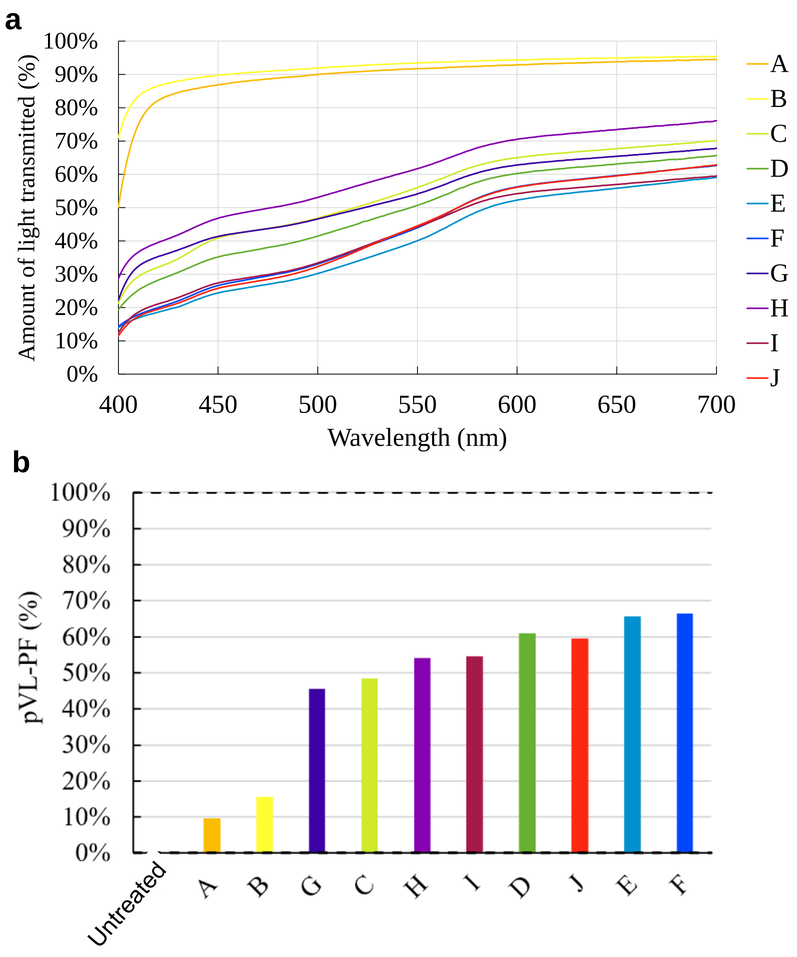

Figure 1: *In vitro* and *in vivo* assessment of 10 sunscreens (A to J): *in vitro* transmission spectrum **(a)**, *in vivo* visible light photoprotection factor as a percentage (pVL-PF) **(b)** and related photos **(c)**

A highly significant correlation was demonstrated between *in vivo* pVL-PF and *in vitro* transmission measurements. Correlations were highest at 420 nm (R^2=0.9910) for distinct wavelengths, and from 400 to 469 nm (R^2=0.9904) for wavelength ranges starting at 400 nm **(Fig. 2)**. This suggests a strong linear relationship between the *in vivo* pVL-PF measurement of sunscreens and the percentage of visible light blocked *in vitro* between 400 and 469 nm, in particular at 420 nm.

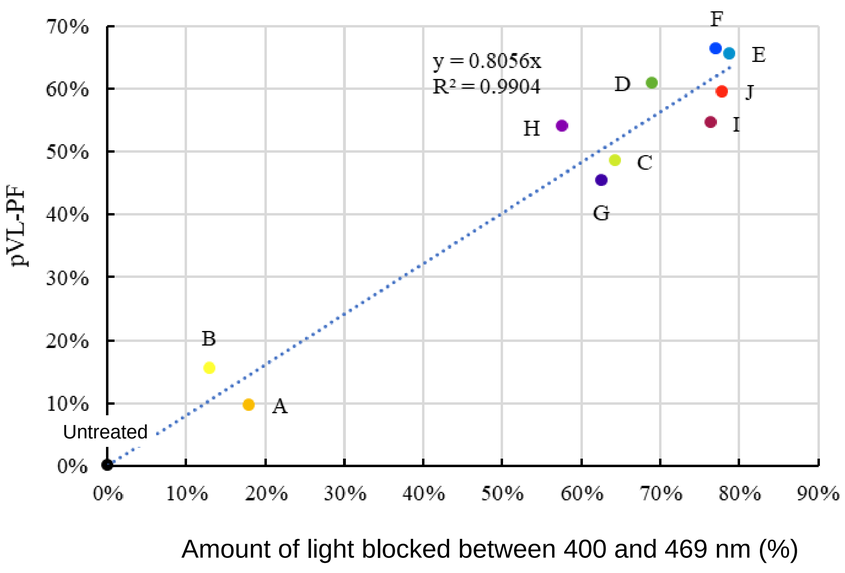

Figure 2: Correlation of photoprotection against visible light measured *in vitro* and *in vivo*

DISCUSSION

pVL-PF is a new interpretation of the original VL-PF for a more intuitive assessment from 0% to 100% of the performance on protection against visible light-induced pigmentation, making it easier to compare various formulations. This should also facilitate the understanding of dermatologists and consumers who are looking for a high level of photoprotection against visible light. Interestingly, the best correlation between *in vivo* pigmentation and *in vitro* transmittance was observed from 400 to 469 nm, which corresponds with the absorption spectrum of opsin-3. Melanocytes detect blue light directly by stimulating the opsin-3[3] receptor.

In conclusion, the *in vitro* method using transmittance measurement from 400 to 469 nm is an appropriate predictive tool when assessing the visible light photoprotection efficacy of sunscreens and could be used to select formulations prior to the final *in vivo* assessment.

Conflicts of interest: TP was an investigator and/or was paid a fee and/or is a consultant for: BDF, HYPHENS, ISIS Pharma, L'OREAL, Mesoestetics, NAOS, Pierre Fabre, SVR, Symrise. LD and CQ-R are employed by the CRO (CPCAD) that conducted the study. BC, IG, FG, CG and AG are NAOS employees.

[1]Lim HW *et al.* J Invest Dermatol 2021 141: 2569-2576; [2]Duteil L *et al.* Photodermatol Photoimmunol Photomed 2017; 33: 260-266; [3]Regazzetti C *et al.* J Invest Dermatol 2018 138:171-178

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