Protection from erythema while accommodating pre-vitamin D_3 production. Are textiles double agents?

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Abstract. Fabric coverings/clothing are commonly advocated as a means of protecting the skin from erythemal producing UV (UV_{ery}) thus reducing skin cancer risk. Conversely, exposure to pre-vitamin D_3 effective ultraviolet ($UVvitD_3$) is essential for health and wellbeing. Observations reveal fabrics present unique transmission profiles with the character of the materials affecting the degree of UV transmission at particular wavelengths. Differences between the pre-vitamin D_3 and erythema producing wavelengths are sufficient to suggest fabrics may both protect from UV_{ery} and maintain transmission of $UVvitD_3$. This paper explores how the erythema and pre-vitamin D_3 action spectra may be used to determine the affect fabrics have on transmission of UV wavelengths associated with erythema and pre-vitamin D_3 production in the skin.

Nationally and internationally adoption of sun protective measures is recommended during peak UV index (UVI) periods when the UVI >3 (Cancer Society, 2010). In New Zealand where UVI values regularly exceed 13 intervention strategies include media promotion of the "slip, slop, slap and wrap, …" action plan reminding people to cover up with clothing, a hat, sunglasses, and to use broad spectrum sunscreens. Such campaigns aim to reduce exposure to both UVA and UVB wavelengths reducing risk of skin cancer. However, sun avoidance has been linked to reduced pre-vitamin D_3 production and vitamin D status in a wide variety of adult populations internationally. Concern is also expressed about the blocking effect of sun screen and clothing and textiles in terms of prevention or reduction of Vitamin D synthesis.

Transmission of UV through textiles has to date generally been expressed as percent total UV transmitted calculated Ultraviolet Protection Factor (UPF) and associated Ultraviolet Protection Rating (UPR) (Standards Australia/Standards New Zealand 1996). More recently researchers have categorised materials in terms of UV transmission behaviour by calculating mean UVA (320 to 400nm) and UVB (290 to 320nm) transmission through materials to evaluate how materials affect these two parts of the spectrum (as well as evaluating UPF and UPR)(Standards Australia/Standards New Zealand 1996). Such approaches do not reveal fabric specific transmission profiles and do not enable fabric specific properties to be exploited. Generating fabric specific profiles enables the potential of materials to protect from erythema producing wavelengths while accommodating production of pre-vitamin D3 generating frequencies to be considered.

The ultraviolet wavelengths commonly associated with production of vitamin D_3 have been the subject of considerable attention over the past few years. Exposure to ultraviolet wavelengths in the pre-vitamin D_3 production range stimulates production of pre-vitamin D_3 in the skin through the conversion of 7-dehydrocholesterol (7-DHC) (Webb 2006). Conversion of 7-DHC, a vitamin D precursor concentrated in the epidermal layers, occurs via a slow, heat induced isomerization.

Most commonly the range for optimum vitamin D production reported is associated with UV frequencies of 300 to 310 or 315nm and this range is generally used in more recent publications which explore the action spectra for Vitamin D_3 synthesis (McKenzie, 2014). However, the pre-vitamin D_3 action spectra is subject to on-going debate. Evolution of the spectra to reflect growing understanding of the process is expected.

The erythemal producing range extends from 280 to 400nm (CIE, 1987). McKenzie, et al. (2010) contends the optimum erythema production range occurs between 290 and 300nm. Consequently, wavelengths necessary for pre-vitamin D_3 and erythema production overlap both the UVB (290 to 320nm) and UVA (320 to 400nm) frequencies. Of interest to those examining effect of materials on erythema and pre-vitamin D_3 production, are the wavelengths most efficient at producing pre-vitamin D_3 as opposed to those associated with erythema and other harmful effects. Because the UVB and $UVvitD_3$ parts of the spectrum overlap, the Standards Australia/Standards New Zealand (1996) method for calculating mean UVA and UVB transmission is not an effective means of evaluating a fabrics UV_{ery} and $UVvitD_3$ character.

Erythema and Pre-vitamin D_3 Action Spectra

Action spectra depict the rate of physiological activity at specific wavelengths e.g. resultant erythema and pre-vitamin D_3 production in the skin. Action spectra for erythema were first proposed in the 1930s with a reference spectra published by CIE in 1987. The CIE erythema action spectrum was produced for use as a "spectral weighting to indicate approximate relative erythemal efficacy of a light source" (Commission Internationale de L'Eclairage, 1987). An equivalent action spectrum for production of pre-vitamin D_3 in human skin was published in 2006 (Commission Internationale de L'Eclairage, 2006). The erythema and pre-vitamin D_3 action spectra have been, and remain, subject to debate. For example, is it appropriate to include a wider range of wavelengths in the action spectra than those responsible for synthesising vitamin D and what are the wavelengths responsible for synthesis? at what wavelength does the action spectrum peak? and what is the relative effectiveness of pre-vitamin D_3 production in different skin types? (McKenzie, et al., 2010, Olds, et al., 2010). The implications of the proposed standardised action spectrum for pre-vitamin D_3 production in human skin, and relationship of this to the recommended daily allowance for vitamin D are also the subject of on-going investigation.

As action spectra plot the rate of physiological activity, in this case production of vitamin D and/or erythema over a range of wavelengths, they enable transmission of

specific frequencies of ultraviolet light to be related to erythema and pre-vitamin D_3 production. Examination of the action spectrum for synthesis of pre-vitamin D_3 reveals that it is currently proposed that only wavelengths below 330nm are used in the synthesis of pre-vitamin D_3 in humans and that the longer UVA wavelengths are not involved (CIE 2006; Webb 1993, 2006).

The current state of knowledge about the action spectra and the relationship of these to skin type is evolving and thus any method using action spectra as a basis for weighting UV transmission through fabrics to estimate erythema and pre-vitamin D3 production must be able to accommodate changes to the action spectra over time.

Weighting UV wavelengths according to the UV erythema and UVvitD$_3$ action spectrums

The CIE action spectra for both erythema (1987) and pre-vitamin D_3 production (2006) were used to weight ultraviolet transmission through the textiles of interest (Wilson, et al., 2013). Units of Erythema ($XEry_{prod}$) and Vitamin D_3 ($VitD_{prod}$) produced as a result of UV transmitted through the fabric, between 290 and 330 nm (at 5 nm intervals), were estimated according to Eqn. 1. Profiles of selected fabrics similar in thickness, mass and UPF are shown in Figure 1 (W-KS-D1 wool, single jersey 0.8mm 197 g/m^2, UPF 36, 16x15 wale x course stitches /10 mm; CP-KE-F6, cotton polyester, eyelet 0.70mm, 166 g/m^2 UPF 44; 22x22 wale x course stitches per 10mm). The 5 nm intervals for measurement were selected to align this preliminary study with the method for measuring UV transmission through textiles specified in AS/NZS 4399:

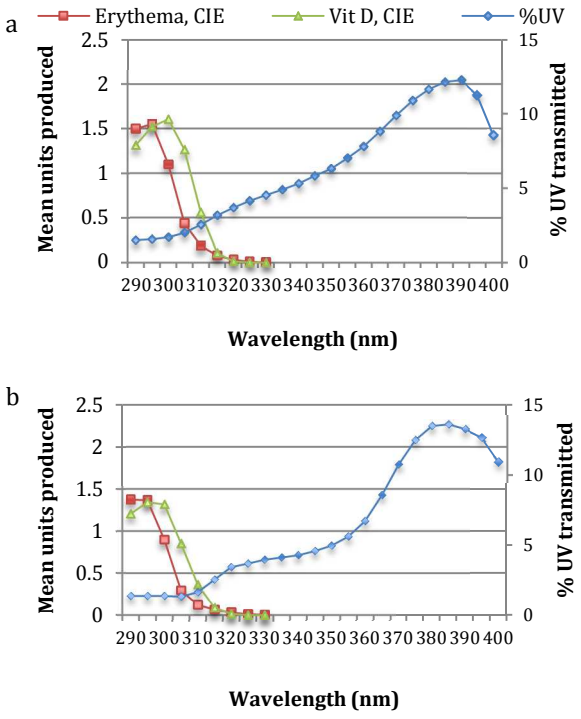

Figure 1. a) Estimated mean units of erythema and pre-vitamin D_3 produced from UV transmitted through a) UPF 36 (very good protection (AS/NZS, 1996)) non-dyed, wool, single jersey fabric (W-KS-D1), and b) UPF 44 (excellent protection) polyester cotton, eyelet fabric (CP-KE-F6)(Wilson, et al., 2013)

1996 (Standards Australia/Standards New Zealand, 1996) thus the estimated units of Erythema and pre-vitamin D3 produced in this study represent approximately 20% of what might be expected if the sum of pre-vitamin D_3 or erythema production (Eqn. 2) were calculated. Anatomical differences in pre-vitamin D3 synthesis in different body regions and the surface area available for synthesis will also affect the sum of pre-vitamin D_3 or erythema production.

$$Mean\ VitD_{prod}\ or\ Mean\ Ery_{prod} = \left(\frac{T_{290}w_{290}+T_{295}w_{295}+\ldots.+T_{325}w_{325}+T_{330}w_{330}}{9}\right) \quad \text{Eqn. 1}$$

$$\sum VitD_{prod}\ or\ \sum Ery_{prod} = T_{290}w_{290}+T_{295}w_{295}+\ldots.+T_{325}w_{325}+T_{330}w_{330} \quad \text{Eqn. 2}$$

UVvitD$_3$ or UV$_{ery}$ weight at □

T_λ = Fabric spectral transmittance at wavelength λ; w_λ = UVvitD$_3$ or UV$_{ery}$ weight at λ

(Wilson, et al., 2013).

Non-dyed fabrics manufactured from the same quarantined yarn, and with no finishing treatments, thus providing a basis for comparison of factors such as fabric structure, were examined to estimate the units of Erythema ($XEry_{prod}$) and Vitamin D_3 ($VitD_{prod}$) produced as a result of UV transmission through these fabrics. Preliminary assessment of the UV$_{ery}$ profiles of the fabrics suggested that specific combinations of fibre, yarn and fabric variables may enable maintenance of protection while accommodating UV$_{vitD3}$ exposure.

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