Protection from solar UV radiation – how important is what you wear and how you wear it?

C.A. Wilson

Clothing and Textile Sciences, University of Otago, Dunedin, New Zealand

Abstract. How fabric properties and conditions of wear affect UV transmission is reviewed and recommendations for manufacture and selection of sun protective garments are discussed.

Exposure to ultraviolet (UV) radiation has been identified as the “most significant environmental factor” leading to skin cancer (Curiskis, Postle and Norton, 1983). Serious implications and effects of exposure to UV are illustrated by skin cancer (the most common form of cancer in New Zealand) case numbers and diagnoses. To address concerns about increasing rates and risk of skin cancer research is directed towards understanding the mechanism(s) causing damage, and how exposure to UV radiation may be reduced. Information campaigns in both New Zealand and Australia have focused on a 'slip, slop, slap and wrap' message advocating use of clothing as one means of reducing exposure to the sun and thus risk.

Sun protective characteristics of clothing have predominantly been investigated using flat fabrics and their capacity to (or not to) transmit UV radiation. Protective rating systems such as UPF (Ultraviolet Protective Factor) ratings have also been developed to communicate to garment buyers the protective rating of the fabric. However, ratings are often extrapolated to imply protective characteristics of garments made from the rated fabrics.

Fabric properties

Properties such as fabric structure (e.g. knitted, woven), thickness, mass, fibre type, extensibility, wetness, and finish (such as use of UV absorbers; choice of colour) affect transmission of UV through fabrics (Bajaj, Kothari and Gosh, 2000; Cox Crews and Kachman, 1999; Davis, Capjack, Kerr and Fedosejevs, 1997; Pailthorpe, 1994).

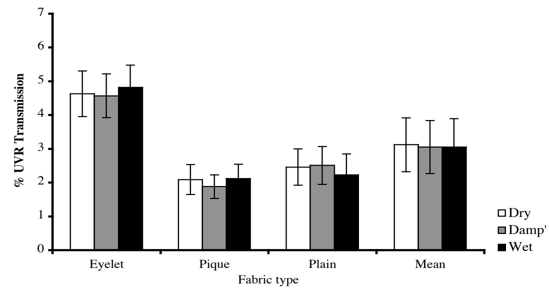
Manufacturing decisions that increase thickness, mass, cover and yarn count, and production of 'darker' colours, are thus likely to be associated with lower UV transmission. However, while many fabric characteristics are correlated with UV transmission relationships are not necessary predictive e.g. in thin woven cotton fabrics count and cover were shown to be poor predictors of UPF (Bajaj, et al., 2000). However, how fabric properties interact to modify UV transmission is not sufficiently understood. Further work is required to clarify relationships between physical characteristics of fabrics and how these affect UV transmission and UPF.

Garments — properties when worn

During use fabric is wrapped around the body in single and/or multiple layers, in relaxed and/or extended configurations and may be dry or wet (either as a result of sweating (localised wetting) or immersion). Only a small number of case studies assessing performance of garments in use and simulated use have been undertaken (e.g. Parisi, Kimlin, Mulheran, Meldrum and Randall, 2000). The effect of use variables such as extension and wetting on UV transmission has been investigated, generally in the laboratory, immediately on wetting, extension etc. and using flat textiles. In the laboratory both extension and wetting fabric have been shown to increase UV transmission (Gambichler, Hatch, Avermaete, Altmeyer and Hoffmann, 2002; Gies, Roy, McLennan and Toomey, 1997; Moon and Pailthorpe, 1995; Pailthorpe, 1994). Interactions, which may modify the relative importance of variables in terms of their effect on UV transmission, have generally not been evaluated.

A laboratory study investigating the effect of i) wetting and extension, and ii) multiple layering of fabrics on transmission (Wilson, Bevin, Niven and Laing, Under review), confirmed the existence of interaction effects with both extension and layering having significantly different effects on transmission depending on the fabric being investigated (Figures 1 a and b). Extension of the eyelet structure resulted in a smaller reduction in UPF compared to that noted for the piqué and plain weave fabrics. Differences were attributed to different effects on the UVA and UVB parts of the spectrum. Wetting also affected fabrics differently (Figure 1a) possibly due to interaction between water and fibre type.

a



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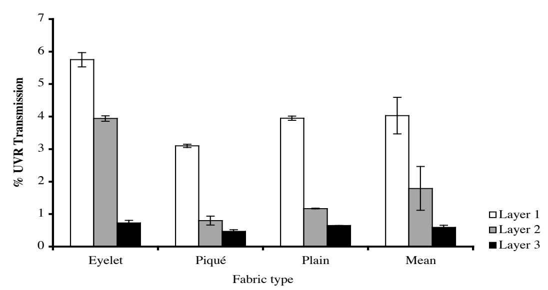

Figure 1. Effect of a) wetting and b) layering on UV transmission

Layering of flat materials also decreased transmission through the high UPF fabrics investigated (Figure 1b). The addition of one layer of fabric reduced transmission of UVA and UVB by 26-74% and 78-86% respectively, with the extent of the reduction varying among fabric types.

Actual UPF during use is also likely to depend on the interaction of fibre and fabric types, associated behaviour when exposed to water (for example, fibre swelling, reduced UV reflectance (Bajaj, et al., 2000)), and drying behaviour (Wilson and Parisi, 2006). Findings suggest wearers selecting garments to be worn in the water may ultimately be able to reduce the detrimental effect of wetting by making specific fabric choices i.e. selection of fibre types less affected by water and those that dry quickly during ongoing use.

Evaluation of two swimwear fabrics exposed to a selection of different types of water (distilled, chlorinated pool and sea water) illustrates how fabric type, type of water, and time of exposure affect transmission (Bau, 2004). Exposure to the different types of water had different effects on transmission over time. Significantly more UV was transmitted through fabric exposed to sea water, less through distilled and pool water (which were not significantly different), and least through fabric exposed to no water. However, the effect of water was dependent on the type of fabric being evaluated. The effect of wetting over time was more apparent on the polyamide/elastane fabric than on the cotton/elastane fabric (Figure 2). Transmission through the cotton/elastane fabric remained the same when exposed to distilled water, decreasing following exposure to pool, and sea water (changes were small but significant). In contrast, transmission through the polyamide/elastane decreased following exposure to distilled water but increased after exposure to pool and seawater suggesting a fibre water interaction may be occurring. Time of exposure was also important. On average UV transmission increased after 25 hours of exposure to water and decreased after 100 hours exposure but did not return to the non-exposed level. Such a change in protective rating with exposure time and water type is unlikely to be detected by wearers but has implications in terms of fabric choice and decisions about duration of product use i.e. some products may have a 'use by' date.

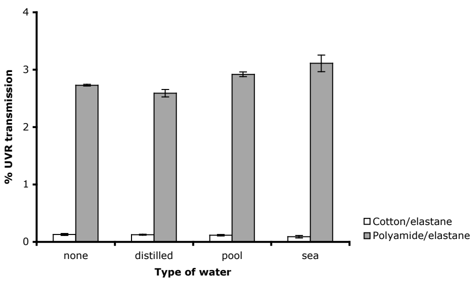

Figure 2. Effect of type of water on mean UV transmission through selected swimwear fabrics

Interactions among variables may influence the relative importance of variables in terms of protection provided during use. During simulated wear fabric type, fit and colour of T-shirts were identified as the main variables affecting UVB transmission (Wilson and Parisi, 2006). Wetness, identified as an important variable affecting transmission during laboratory testing, was not important when manikins wearing the garments (Figure 3) were exposed to sunlight for 3 hours. Results suggest that environmental conditions and fabric properties such as drying time have implications in terms of the effects of fabric wetness during use. During use once the fabric type had been selected to minimise transmission the fit of the product, and by implication the space between the skin and fabric, was more important than colour and wetness. Loose fitting T-shirts, which implies less fabric extension and a thicker underlying air space, reduced transmission significantly more than the fitted style.

Figure 3. Manikin wearing a black, loose fit T-shirt

What guidelines can be inferred

Designers of sun protective clothing should continue to select fabrics that are heavier, thicker, higher in cover and in darker colours, but should also create sun protective designs that are loose fitting, maximise surface area covered and which include and/or accommodate layering. From a users perspective garments will be most effective if as well as fabric properties issues of fit, use of layers, and styles that cover more surface area are considered during garment selection and use.

References

Bajaj, P., Kothari, V. K. and Gosh, S. B. 2000. Review article: some innovations in UV protective clothing. *Indian J. Fibre Text. Res.* 25 (4): 315-329.

Bau, S. 2004. Effect of exposure to distilled, chlorinated pool, and sea water on UV transmission through selected swimwear fabrics over time. Dunedin, New Zealand: Unpublished report. Clothing and Textile Sciences, University of Otago.

Cox Crews, P. and Kachman, S. 1999. Influences on UVR transmission of undyed woven fabrics. *Text. Chem. Color.* 31 (6): 17-26.

Curiskis, J. I., Postle, R. and Norton, A. H. 1983. Fabric engineering - present status and future potential. In *Objective Evaluation of Apparel Fabrics*, Edited by Postle, R., Kawabata, S. and Niwa, M. 539-550. Osaka: The Textile Machinery Society of Japan.

Davis, S. G., Capjack, L., Kerr, N. and Fedosejevs, R. 1997. Clothing as protection from ultraviolet radiation: which fabric is most effective. *Int. J. Dermatol.* 36 (5): 374-379.

Gambichler, T., Hatch, K. L., Avermaete, A., Altmeyer, P. and Hoffmann, K. 2002. Influence of wetness on the ultraviolet protection factor (UVP) of textiles: in vitro and in vivo measurements. *Photodermatol. Photoimmunol. Photomed.* 18: 29-35.

Gies, P. H., Roy, C. R., McLennan, A. and Toomey, S. 1997. Clothing and protection against solar UVR. *J. HEIA* 4 (3): 2-6.

Moon, R. and Pailthorpe, M. 1995. Effect of stretch and wetting on the UPF of elastane fabrics. *Australasian Text.* 15 (5): 39,41-42.

Pailthorpe, M. T. 1994. Textile and sun protection: the current situation. *Australasian Text.* 14 (6): 54,56,59,61-62,64,66.

Parisi, A. V., Kimlin, M. G., Mulheran, L., Meldrum, L. R. and Randall, C. 2000. Field-based measurements of personal erythemal ultraviolet exposure through a common summer garment. *Photodermatol. Photoimmunol. Photomed.* 16 (3): 134-138.

Wilson, C. A., Bevin, N. K., Niven, B. E. and Laing, R. M. Under review. Solar protection — Effect of selected fabric characteristics of UV transmission. *Text. Res. J.*

Wilson, C. A. and Parisi, A. V. 2006. Protection from solar erythemal ultraviolet radiation — simulated wear and laboratory testing. *Text. Res. J.* 76 (3).