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Measurements of occupational ultraviolet exposure and the implications of timetabled yard duty for school teachers in Queensland, Australia: Preliminary results

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ABSTRACT

Simultaneous personal measurements of the occupational ultraviolet exposure weighted to the International Commission on Non-Ionising Radiation Protection hazard sensitivity spectrum (UV_{ICNIRP}) were made over a five week period (44 person-days) in the second half of the summer school term of 2012 in Queensland, Australia for individual high school teachers located at latitudes of 27.5°S and 23.5°S. These teachers were employed for the duration of the study in a predominately indoor classroom teaching role, excluding mandatory periods of lunch time yard duty and school sport supervisions. Data is presented from personal measurements made to the shirt collar using polyphenylene oxide (PPO) film UV dosimeters. UV_{ICNIRP} exposure data is presented for each week of the study period for the shirt collar measurement site and are further expressed relative to the measured ambient horizontal plane exposure. Personal exposures were correlated with time outdoors, showing a higher exposure trend on days when teachers were required to supervise outdoor areas for more than 2 h per week (mean daily exposure: 168 J m^{-2} UV_{ICNIRP} ± 5 J m^{-2} (1σ)) compared to the study average (mean daily exposure: 115 J m^{-2} UV_{ICNIRP} ± 91 J m^{-2} (1σ)). Time spent in an open playground environment was found to be the most critical factor influencing the occupational UV_{ICNIRP} exposure. A linear model was developed showing a correlation (R^2 = 0.77) between the time teachers spent on yard duty and UV_{ICNIRP} exposure, expressed relative to ambient. The research findings indicate a greater reduction in personal exposure can be achieved by timetabling for yard duty periods in playground areas which offer more shade from trees and surrounding buildings. All mean daily personal exposures measured at the shirt collar site were higher than the ICNIRP occupational daily exposure limit of 30 J m^{-2} for outdoor workers.

1. Introduction

Skin cancers and eye disorders such as cataracts caused by exposure to solar ultraviolet radiation [1] are a significant cost burden to health authorities throughout the world. In Australia, the cost burden for diagnosing and treating non-melanoma skin cancer alone has been measured at over $264 million [2] and compares to an annual skin cancer treatment cost in the United States of over $2 billion [3]. The cost in Australia is exceedingly high because of two primary factors. Firstly, a very high ambient ultraviolet climate due to high annual solar elevation in the mid to low latitudes of Australia's geographic location, lower moderation of biologically significant ultraviolet B (UVB: 280–320 nm) due to generally lower stratospheric ozone concentrations compared to the northern hemisphere and a closer earth sun distance during the southern hemisphere summer compounding the threat posed by the naturally available UVB spectrum. Secondly, an outdoor lifestyle promoted by a warm Australian climate and a predominately fair skinned population increases the risk of over exposure and the development of skin cancer. Excessive exposure to this UVB radiation is preventable and strategies promoted by public health campaigns such as the Australian "Slip Slop Slap" and "SunSmart" public education program advocate improving sun-related attitudes and behaviour with the result being an increased awareness among the population compared to earlier decades for an estimated 22,000 life years saved since the program's introduction in the 1980's [4]. Also on the positive side, there has been a recent stabilization in mortality rates for melanoma skin cancer across Australia, the US and European countries [5]. However, the worldwide disease burden in terms of cost and incidence continues to rise [5]. In Australia, over 1200 deaths are attributed to the development of melanoma skin cancer with more than 400 deaths being attributed to the development of other types of non-melanoma skin cancer annually [6].

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Deaths due to non-ionising exposure to ultraviolet radiation as a result of occupation are more difficult to analyse statistically. This is largely due to limited information being available on lifetime exposure habits. Interestingly, occupations which require long periods of time outdoors, construction and outdoor labouring positions for example, do not show a strong correlation with skin cancer [7,8]. Lee and Strickland [9] report a lower incidence and mortality from malignant melanoma for unskilled workers compared to professional and administrative workers whose occupation places them largely in an indoor environment. Yet exposure to UVB radiation is known to be the most significant risk factor for the development of malignant melanoma, the most common type of cancer in fair skinned populations [5]. This has been deduced from studies of past lifetime sun exposure histories, a large bank of information linking high skin cancer incidence to high UVB ambient climates such as those experienced in Australia and studies involving animals [10].

Intermittent exposure to sunlight received as a consequence of occupation has been found to induce melanoma [11]. Intermittent exposures for workers placed into primarily indoor roles remains an important risk factor to be studied in order to better determine the epidemiology of sun related disease. Of those indoor population groups at risk of exposure to non-ionsing UVB, school teachers are particularly interesting as they are largely employed in indoor classroom roles but must also frequently supervise children in an outdoor playground environment. Several studies have measured UVB exposure to school children and have been developed to explain the local ambient UV in a school playground [12–14]. Other studies have examined the exposure received by school teachers themselves. Woolley et al. [15] recommended the mandatory use of appropriate sun protective clothing for individuals in high sun exposure occupations. Although limited to adult men, this study also noted that sun protection measures had a tendency to be adopted only by those who had a previous negative experience with skin cancer [15]. Young teachers and school children are unlikely to have first-hand experience with skin cancer due to the tendency for a long latency period between exposure and the development of the disease.

Indeed, the importance of better understanding the UVB exposures received by indoor population groups has begun to gather momentum. A summary of personal exposures expressed relative to the available ambient ultraviolet for both indoor and outdoor occupational groups has been presented by Godar [16]. A comparison of these studies show that exposures received by outdoor workers, including gardeners, lifeguards, physical education teachers and other outdoor occupations are roughly twice that of indoor workers and vary depending upon the available ambient in which the studies were conducted [16]. Studies conducted by Gies et al. [17] and Vishvakarmen et al. [18] have measured the biologically significant UVB exposure to school teachers and have provided a better understanding of the intermittent and cumulative lifetime exposures received by this indoor/outdoor occupational group, however these studies considered the exposure received by Physical Education teachers, who spend a proportionally high amount of time in an outdoor environment. In this research, a long term UVB dosimeter was employed to quantify the exposure received by school teachers employed primarily as indoor classroom teachers with specific reference to the International Non-Ionising Radiation Committee recommendations on occupational exposure limits to biologically significant UVB.

2. Materials and methods

A personal UV monitoring program was established over a consecutive five week period of the Queensland school teaching term running from 29 October to 30 November, 2012. The study period coincides with seasonal peak ultraviolet playground exposures in the Australian school teaching calendar, ending in mid December, toward the approach of summer solstice for summer break and beginning again in late January, a time when the earth sun distance is at a minimum. Both school populations, including children and staff in this study were of a predominantly fair skin type (Fitzpatrick skin type Type I and Type II).

The monitoring program measured the incident ultraviolet radiation weighted to the occupational ultraviolet hazard sensitivity standard (UV_{ICNIRP}). The UV_{ICNIRP} represents the spectrally weighted occupational exposure standard and is based on the amended 1989 guidelines on exposure limits to UV radiation received by the skin or eye of the International Non-Ionising Radiation Committee (*INIRC*) of the International Radiation Protection Association (*IRPA*) [19]. The IRPA [20] standard has been issued as the threshold limiting exposure of the World Health organisation [21] and may be taken as representative of the upper daily exposure limit for the working population. The UV_{ICNIRP} exposure applies a lower spectral weighting to wavelengths below a normalised peak at 290 nm than other comparative action spectra and when weighted, is lower than exposures referenced to the erythemal action spectrum [22]. Thus the measurements presented here are likely to be higher if taken as indicative of the human erythemal or sunburning response. The recommended exposure limit referenced to the occupational standard received by outdoor workers over an 8-h daily exposure period is 30 J m^{-2} [19].

Measurements of personal UV_{ICNIRP} exposure were made for the current study to two Queensland high school teachers located in Toowoomba (27.5°S, 151.9°E) – participant A, and Emerald (23.5°S, 148.2°E) – participant B, Queensland, Australia. Both teachers were employed as indoor classroom teachers but were expected to partake in mandatory outdoor playground and sport supervision duties as part of their employment. Emerald, located at sea level is situated in a rural setting, while Toowoomba at 690 m altitude is a regional Australian city of approximately 125,000 people. Both cities have a limited industrial capacity and experience minimal air pollution, predominately clear skies and high ultraviolet exposure climates relative to other schools with similar fair skin type populations located in higher European or North American latitudes.

Measurements were made using a miniaturised version of a polyphenylene oxide (PPO) film dosimeter [23–27]. These dosimeters are manufactured at the authors' research laboratory at the University of Southern Queensland, Toowoomba, Australia in thin film form to an approximate thickness of 40 μm. The film was attached to flexible polymer frames measuring 15 by 10 mm with a clear circular aperture of 7 mm. The PPO film dosimeters used have the advantage of an extended dynamic range compared to polysulphone and were used for five consecutive working days before replacement. Dosimeter sets exposed in Toowoomba and Emerald were calibrated to a predetermined calibration function:

$$UV_{ICNIRP} = -2595.2\ \Delta A_{320}^2 + 8969\ \Delta A_{320} \quad (1)$$

Here, UV_{ICNIRP} is the calibrated INIRC/IRPA [19] weighted UV, and ΔA_{320} is the change in dosimeter absorbance measured at 320 nm. The quadratic calibration function was determined by exposing a series of miniaturised PPO dosimeters between 5 and 9 November 2012 at the University of Southern Queensland, Toowoomba. Thus calibrated exposures measured to participant A are representative of the same ambient conditions under which the calibration was performed for the early summer solar zenith angle range and ozone conditions. Measurements to participant