Original Research

Patterns of real-time occupational ultraviolet radiation exposure among a sample of outdoor workers in New Zealand

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SUMMARY

Objectives: Exposure to solar ultraviolet radiation (UVR) is an occupational health and safety issue for outdoor workers since excessive exposure is associated with negative health outcomes, including eye conditions and skin cancers. The objective of this research was to describe the pattern of UVR exposure experienced by outdoor workers from selected occupations in New Zealand in order to identify the impact of behaviour and work conditions on exposure.

Study design: This paper reports on the occupational UVR exposure arm of a dual arm cross-sectional study that also examined workers’ sun protection practices.

Methods: For five consecutive working days in January–March 2007, electronic dosimeters were used to record the time-stamped UVR exposure of a sample of 77 outdoor workers from three occupations (building, horticulture and roading) in Central Otago, New Zealand.

Results: The geometric mean total daily UVR exposure (between 1100 and 1600 h) was 5.32 standard erythemal doses (SED; 95% reference range 0.28–19.97 SED). The geometric mean total daily UVR exposure as a percentage of the total daily ambient UVR was 20.5% (95% confidence interval 1.4–83.0%). Personal UVR exposure dipped between 1200 h and 1300 h – the same time that ambient UVR peaked – indicating the effect of shade seeking over the lunch period. Personal UVR exposure peaked between 1400 h and 1500 h, alongside decreasing ambient UVR levels, suggesting the influence of behavioural rather than climatic factors. The difference in workers’ exposure between 1200 h and 1300 h, and 1400 h and 1500 h was statistically significant for both measured personal exposure (P < 0.005) and exposure calculated as a percentage of concurrent available ambient UVR (P < 0.005).

Conclusions: All the workers in this study recorded mean daily UVR exposure in excess of the current recommended occupational exposure limits. Only a minority of workers sought shade during their lunch break; most remained in highly exposed conditions. There is no evidence that work tasks which involve substantial sun exposure are being scheduled outside the high UVR period.

Introduction

Skin cancer is linked to excessive exposure to ultraviolet radiation (UVR). It is the most common cancer, and the World Health Organization has reported that excessive solar UVR exposure results in 60,000 premature deaths per year worldwide. Of these, an estimated 48,000 were the result of malignant melanomas and 12,000 were from skin carcinomas.

Despite this, skin cancer is largely considered to be preventable through the use of sun protection strategies, such as covering exposed skin and the use of shade. Due to their prolonged, cumulative sun exposure, those who work outdoors are particularly susceptible to the harmful consequences of spending too much time in the sun, particularly non-melanoma skin cancer. It has been estimated that New Zealand (NZ) has approximately 250,000 outdoor workers spread across a range of occupations, in a total population of 4,261,388. This equates to approximately 14% of the total workforce. Although often confounded by concurrent leisure time sun exposure, and prone to self-selection bias, studies from the USA, UK and Japan have detected a significant association between skin cancer and outdoor occupation. In Australia, non-melanoma skin cancers were found to be twice as prevalent among outdoor workers compared with indoor workers. Clearly, exposure to solar UVR is an important occupational health issue for outdoor workers.

Although there is no NZ standard or legislation that prescribes maximum permissible UVR exposure, excessive exposure is acknowledged as a potential occupational risk by the NZ...
Department of Labour.\textsuperscript{12} To comply fully with the NZ ‘Health and Safety in Employment Act 1992’, exposure to UVR must be identified and assessed as a potential hazard, and appropriate controls must be implemented and monitored. However, the available evidence suggests that adequate control strategies are not widely implemented, and many outdoor workers remain at high risk of developing skin cancer.

To date, no attempts have been made to measure the personal UVR exposure of NZ outdoor workers. This study used time-stamped electronic UVR dosimeters to describe the pattern of occupational solar UVR exposure experienced by a sample of NZ outdoor workers from selected occupations in order to help identify the impact of behaviour and work conditions on UVR exposure.

Methods

Study design

This paper reports on the UVR exposure arm of a dual arm, cross-sectional study that also examined sun protective practices, and skin-cancer-related knowledge, attitudes and perceptions in a sample of NZ outdoor workers. Participating workers had their personal occupational solar UVR exposure measured for five consecutive working days during months when, for most hours during the working day, ambient UVR exceeds levels for which protective strategies are recommended (from UVI level three upwards for people who are spending long periods in the sun).\textsuperscript{14} The study was conducted from mid-January to early March 2007 in Central Otago, NZ.

Participants

Participants were drawn from a convenience sample of three major outdoor occupational groups: horticulture (including viticulture), roading (including paving) and building (including roofers). No convenient sampling frame for outdoor workers was available. All identified workplaces of these outdoor occupational groups in the Central Otago geographical region (45° S, alt 0.37 km) were approached to take part in the study.

In order to be included, workers needed to be employed in outdoor occupations and able to be recruited through employers with five or more eligible staff. Employers with fewer than five staff were excluded in order to optimize use of the limited, seasonal fieldwork time available. The inclusion criteria stipulated that workers must usually work outdoors between the hours of 1000 h and 1600 h, during daylight saving months, for 5 days per week.

Using the range of UVR exposures [0.47–26.23 standard erythemal doses (SED)] reported in an Australian study,\textsuperscript{15} the estimated standard deviation of daily UVR exposure is 0.77 on the log scale (based on simulations). A sample of 50 workers would allow exposure to be estimated within $\pm 0.05$ in all cases.

Procedures

Personal erythemal UVR exposure was measured using lithium battery powered UVR detectors (range 280–320 nm) with on-board data logging capabilities and clock. A time-stamped measurement was logged every 8 s and stored in electronically erasable programmable read-only memory until downloaded to a laptop computer. The UVR monitor comprised a Schottky A1GaN (A1 26%) photodiode and required electronics encased in a waterproof case made from shaped polytetrafluoroethylene (PTFE). The A1Gan photodiode has a spectral response that closely matches the erythemal action spectrum,\textsuperscript{16} and the shaped PTFE case provides a good cosine response.\textsuperscript{17} The UVR monitor weighed 20.7 g with a diameter of 35 mm and a thickness of 13 mm, allowing it to be pinned on to clothing as a badge. The UVR monitor was programmed to start recording at 0700 h and stop recording at 2000 h each day. All times were NZST+1 since the study was conducted during daylight saving months.

By using the sun as a source on 10 consecutive days in January 2007, the UVR monitors were calibrated against a second-generation ‘Robertson-Berger’ meter model UVB-1 manufactured by Yankee Environmental Systems and maintained by the National Institute of Water and Atmospheric Research (NIWA) at Lauder, NZ. To measure comparable doses, all UVR monitors were supplied with individual calibration coefficients, after fitting a second order polynomial equation to the regression plot to compensate for the UVR monitor’s slight underestimate of UVR at low solar zenith angles.\textsuperscript{18} Ambient UVR data were recorded at the NIWA site throughout the duration of the study.

Each consenting participant was issued with a personal UVR monitor and asked to attach it to the rear collarbone (scapular) area of their outer layer of clothing from ‘the time they start work until the time they finish work for the day’. Data from the personal UVR monitors were downloaded after Day 5 of the study period.

Analysis

All UVR exposures are described in SED units, the recommended unit for expressing personal UVR exposure\textsuperscript{18} where 1 SED = 100 J m\textsuperscript{-2} normalized to 298 nm according to the International Commission on Illumination erythemal action spectrum.\textsuperscript{16,19}

An exposure of approximately 1.5–3.0 SED is required to produce perceptible erythema in unacclimatized white skin.\textsuperscript{20}

Workers’ UVR exposure was calculated in three ways: (1) as mean total daily personal UVR exposure (SED) over the peak UVR hours (1100–1600 h); (2) as hourly exposure (SED/h) over this same period, and to reduce the influence of season and weather conditions, as (3) a percentage of the concurrent ambient UVR. Percentage ambient UVR was calculated as the workers’ personal UVR for a given time period divided by the concurrent available ambient UVR. Fig. 1 presents UVR exposure patterns over the working day.

Differences in exposure between occupational groups (both absolute and percentage of ambient) were examined using general linear models controlling for clustering within workplaces and repeated measures for employees. Differences in lunch time and afternoon exposure were analysed similarly. All analyses were conducted using Stata version 10.1. Statistical significance was determined by $P < 0.05$ in all cases.

Results

Of the 40 workplaces invited to participate, 27 were excluded: staff numbers were too low (less than five potential participants) in 14 workplaces; 10 did not respond to the invitation and could not be contacted by telephone; two declined; and one was excluded during fieldwork due to staff annual leave. In total, 13 workplaces and 77 workers took part in this study. Workplaces not contacted were spread across occupational groups, and the time of recruitment (December 2006, the beginning of the annual holiday period) was likely to be a contributing factor to non-participation. Of the 77 eligible workers, complete data were only available for 74 participants due to malfunction of three instruments.

The mean age of workers was 35 years (range 15–66 years), and 82% were male. Fifty-three percent of participants were builders, 26% were road workers and 22% were horticulture workers.
Sample demographic characteristics

Participants’ demographic characteristics (based on 74 workers) are presented in Table 1.

Solar UVR exposure

Ambient environmental conditions

A summary of the daily mean ambient UVR for the peak UVR period (1100–1600 h) and ambient UVR levels (measured at Lauder, Central Otago, NZ) by study week is provided in Table 2. Weekly differences in total daily ambient UVR levels are evident, with the highest mean values recorded in Week 4 and the lowest mean values recorded in Week 7.

Total daily UVR exposure

Since actual work hours varied between workplaces, only exposure between 1100 h and 1600 h, when ambient UVR levels are at their highest, was considered in this study. There were 8 days when a worker forgot to attach their monitor, 14 person-days off work due to Waitangi Day (a national public holiday, 6 February), 6 person-days off work due to rain, and 2 person-days off work due to sick leave, resulting in a total of 340 person-days of UVR data.

The geometric mean daily UVR exposure, percentage ambient UVR exposure and 95% reference ranges for each occupational group are presented in Table 3. There was no significant difference in personal UVR exposure ($P = 0.95$) or percentage ambient exposure ($P = 0.92$) between occupational groups.

A significant difference in sun protection scores between occupational groups was evident ($P = 0.01$). Post-hoc tests indicated that horticulture workers’ sun protection was significantly higher than that of road workers ($P < 0.01$) and builders ($P < 0.01$). There was no significant difference between builders and road workers ($P = 0.23$). Further details about the sun protection score and sun-related knowledge, attitudes and beliefs of the workers in the present study are available elsewhere.

The arithmetic mean outdoor ambient UVR, geometric mean personal UVR, and percentage ambient UVR exposure by hour of the day, for all days, are presented in Fig. 1.

As one would expect, the highest mean hourly ambient UVR exposure was between 1200 h and 1300 h at 6.48 SED, and the mean percentage of ambient UVR to which workers were exposed was lowest at this time (13.6%). Despite decreasing availability of ambient UVR, the highest mean personal UVR exposure was between 1400 h and 1500 h, with the highest percentage ambient UVR exposure also recorded at this time (25.7%).

The authors tested for a difference in UVR exposure received by the participants between 1200–1300 h and 1400–1500 h, controlling for clustering within workplaces, and found that the mean exposure

### Table 1

Demographic characteristics of sample, by occupational group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Builders</th>
<th>Horticulture workers</th>
<th>Road workers</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>Total</td>
<td>39 (53)</td>
<td>16 (22)</td>
<td>19 (26)</td>
<td>74 (100)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>38 (97)</td>
<td>4 (25)</td>
<td>19 (100)</td>
<td>61 (82)</td>
</tr>
<tr>
<td>Female</td>
<td>1 (3)</td>
<td>12 (75)</td>
<td>0 (0)</td>
<td>13 (18)</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–30</td>
<td>15 (38)</td>
<td>9 (56)</td>
<td>8 (42)</td>
<td>32 (43)</td>
</tr>
<tr>
<td>31–45</td>
<td>14 (36)</td>
<td>3 (19)</td>
<td>7 (37)</td>
<td>24 (32)</td>
</tr>
<tr>
<td>46–60</td>
<td>10 (26)</td>
<td>4 (25)</td>
<td>4 (21)</td>
<td>18 (24)</td>
</tr>
<tr>
<td>Skin type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just burn, not tan</td>
<td>4 (10)</td>
<td>2 (12)</td>
<td>1 (5)</td>
<td>7 (9)</td>
</tr>
<tr>
<td>Burn first, then tan</td>
<td>30 (77)</td>
<td>9 (56)</td>
<td>14 (74)</td>
<td>53 (72)</td>
</tr>
<tr>
<td>Not burn at all</td>
<td>5 (13)</td>
<td>4 (25)</td>
<td>4 (21)</td>
<td>12 (16)</td>
</tr>
<tr>
<td>Unsure/missing</td>
<td>0 (0)</td>
<td>1 (6)</td>
<td>0 (0)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Ethnic groupa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Zealand European</td>
<td>38 (97)</td>
<td>16 (100)</td>
<td>19 (100)</td>
<td>73 (98)</td>
</tr>
<tr>
<td>Maori</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Chinese</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Secondary educationb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>32 (82)</td>
<td>14 (88)</td>
<td>12 (63)</td>
<td>58 (75)</td>
</tr>
<tr>
<td>No</td>
<td>7 (18)</td>
<td>2 (12)</td>
<td>7 (37)</td>
<td>16 (21)</td>
</tr>
</tbody>
</table>

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a More than one ethnic group may be selected Note: due to rounding, percentages may not total 100.

b Refers to the presence of any secondary school qualification equivalent to year 11 upwards.
between 1400 h and 1500 h was, on average, 0.50 SED higher than the mean exposure between 1200 h and 1300 h \( (P < 0.01, 95\% \text{CI}_{\text{diff}} 0.33–0.67 \text{ SED}) \). The same approach was used to look for a difference in percentage ambient UVR exposure received by the participants between 1200–1300 h and 1400–1500 h, and the mean percentage ambient exposure between 1400–1500 h was found to be, on average, 14.5% higher than that between 1200 h and 1300 h \( (P < 0.01, 95\% \text{CI}_{\text{diff}} 11.5–18.3\%) \). While these were unplanned comparisons, the \( P \)-values are both highly statistically significant \( (<0.001) \).

**Discussion**

This study was the first to measure the real-time, personal occupational UVR exposure of a sample of NZ outdoor workers. Overall, most workers in this study received high daily levels of UVR exposure. The geometric mean UVR exposure for all workers was 5.32 SED. No worker recorded UVR exposure below the recommended current occupational exposure limits.\(^2\) Similarly, an Australian study of construction workers found that only 10% of participants received UVR exposure below the limit.\(^5\) The mean daily personal exposure of the workers in this study is similar to the median daily exposure of lawn mowing contractors in Austria,\(^2\) German mountain guide instructors (based on a year’s measurement)\(^4\) and Australian construction workers,\(^5\) but lower than the summer mean daily exposure of postal workers and physical education teachers in Australia,\(^2\) and building workers in Switzerland,\(^6\) and higher than the mean daily exposure of Irish and Danish gardeners.\(^7\) However, comparing the results of the present study with those of other personal UVR dosimetry studies is problematic because of differences in study design, such as the anatomical attachment site of the personal UVR monitor. UVR exposure is known to vary significantly between sites,\(^4\) measurement duration, latitude, season, weather conditions and altitude. Furthermore, the amount of UVR actually received depends on the protective practices adopted. An earlier report found that the sun protection practices of the workers in this sample were generally moderate, with an average of 72.6% body coverage.\(^2\)

Total daily UVR exposure as a percentage of ambient UVR was calculated to reduce the effects of weather and seasonal differences and to facilitate comparisons. The mean exposure, expressed as a percentage of the available ambient UVR, was 20.5%, which is less than the median percentage of ambient UVR found in a large study of construction workers (26%),\(^15\) and that of physical education teachers, gardeners, lifeguards, a carpenter and a bricklayer in Australia.\(^28,29\)

There were no statistically significant differences in UVR exposure between the occupational groups. This is surprising as it was anticipated that builders would have lower exposure, since the structures on which they work provide some shade. Also, horticulture workers were expected to benefit from some shelter from trees, resulting in less exposure than road workers who often work in remote areas where there is no built or natural shade. Similar to previous studies,\(^15\) the 95% reference intervals for mean UVR exposure and percentage ambient exposure reported here indicate that considerable within-group variation in UVR exposure is evident. This may have reduced the ability of this moderately sized study to detect a difference in UVR between the surveyed occupational groups.

There were no significant differences in the percentages of ambient exposure of the workers by gender or age. There was no evidence for any differential behaviour or treatment of workers in terms of sun exposure; for example, allotting high-exposure jobs, such as building a fence, to young apprentices.

When considering total UVR exposure by hour, an interesting pattern emerges. The lowest hourly mean percentage ambient exposure (13.6%) was recorded in the period between 1200 h and 1300 h. From this, it can be concluded that some workers sought shade during their lunch break. The highest mean personal UVR exposure per hour (1.36 SED) was between 1400 h and 1500 h, when it can be reasonably assumed that workers had returned to work from lunch. The highest mean percentage ambient exposure (25.7%) also occurred in this time period, suggesting that this increased UVR exposure was influenced by behavioural rather than climatic factors. The difference in workers’ exposure between 1200 h and 1300 h, and 1400 h and 1500 h, when expressed as both measured personal and percentage ambient UVR exposure, was statistically significant \( (P < 0.01 \text{ in both cases}) \). On average, workers received slightly over 0.5 SED more UVR, and their percentage ambient UVR exposure was 17.2% higher between 1400 h and 1500 h compared with their lunch break (1200–1300 h). Ideally, workers should be rescheduling work tasks that involve substantial sun exposure by delaying them until late afternoon, for example, but the findings from this study suggest that this is not happening in practice.

Results indicated that although a minority of workers were seeking shade in their lunch break, there was considerable room for further improvement. The decrease in percentage ambient UVR exposure over the lunch period could, perhaps, be further reduced by efforts to promote and increase the provision of comfortable, practical and adequate shade. However, gains from this strategy are not a certainty, as four studies reveal that seeking shade is an uncommon protection strategy among outdoor workers.\(^30–33\)

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**Table 2**

<table>
<thead>
<tr>
<th>Study week</th>
<th>First day</th>
<th>Last day</th>
<th>Mean ambient UVR between 1100 h and 1600 h (SED)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22 January</td>
<td>26 January</td>
<td>27.38</td>
</tr>
<tr>
<td>2</td>
<td>29 January</td>
<td>2 February</td>
<td>26.25</td>
</tr>
<tr>
<td>3</td>
<td>5 February</td>
<td>9 February</td>
<td>34.88</td>
</tr>
<tr>
<td>4</td>
<td>12 February</td>
<td>16 February</td>
<td>37.89</td>
</tr>
<tr>
<td>5</td>
<td>19 February</td>
<td>23 February</td>
<td>30.31</td>
</tr>
<tr>
<td>6</td>
<td>26 February</td>
<td>2 March</td>
<td>30.62</td>
</tr>
<tr>
<td>7</td>
<td>5 March</td>
<td>9 March</td>
<td>23.52</td>
</tr>
</tbody>
</table>

SED, standard erythemal dose.

---

**Table 3**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Builders</th>
<th>Horticulture workers</th>
<th>Road workers</th>
<th>Overall</th>
<th>( P ) value(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean daily UVR exposure</td>
<td>5.25</td>
<td>5.61</td>
<td>5.32</td>
<td>5.32</td>
<td>0.95</td>
</tr>
<tr>
<td>(95% reference range)</td>
<td>(2.28–9.09)</td>
<td>(2.09–23.71)</td>
<td>(0.28–16.12)</td>
<td>(0.28–19.97)</td>
<td></td>
</tr>
<tr>
<td>Mean daily percentage ambient UVR</td>
<td>19.6</td>
<td>24.0</td>
<td>20.5</td>
<td>20.5</td>
<td>0.92</td>
</tr>
<tr>
<td>(95% reference range)</td>
<td>(1.6–66.4)</td>
<td>(1.4–80.7)</td>
<td>(1.2–105.2)</td>
<td>(1.4–83.0)</td>
<td></td>
</tr>
<tr>
<td>Sun protection score(^d)</td>
<td>72.1</td>
<td>78.3</td>
<td>69.0</td>
<td>72.6</td>
<td>0.01</td>
</tr>
<tr>
<td>(95% reference range)</td>
<td>(61.03–96.65)</td>
<td>(59.4–87.3)</td>
<td>(49.1–92.0)</td>
<td>(51.71–94.81)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) \( P \) value is for the overall test of differences between groups based on one-way analysis of variance.

\(^b\) Upper limit reference interval for road workers exceeds 100%, presumably due to reflection.

\(^c\) A score of 100 indicates complete body surface protection; see Hammond et al. (2008) for method of assessment.

\(^d\) A score of 100 indicates complete body surface protection; see Hammond et al. (2008) for method of assessment.
although it is unclear to what extent this behaviour may be related to shade availability.

Given the above, an intervention study which included the provision of shade would be beneficial, in conjunction with the use of dosimeters to give objective evidence for shade use. This would clarify whether advocating for mandatory shade provision by employers (perhaps under the Health and Safety in Employment Act) would be a worthwhile protective strategy.

Real-time exposure data suggest that it may be useful to remind workers of the risks associated with spending increased time in the sun between 1100 h and 1600 h. Using the lunch break to increase personal protection should be emphasized. As well as advising workers to seek shade during their lunch break, they should be advised to work in shaded areas where possible during the period leading up to 1600 h. For example, it is possible to follow shade around the construction of a building. High-exposure tasks such as mapping and laying foundations should be left for mornings or late afternoons in the summer months. However, given that 93% of workers in this study reported that they could not reschedule their tasks to avoid working in the sun during peak UVR periods, these messages should be directed towards employers. Glanz et al. suggest that workers’ inability to schedule their day highlights the employer’s responsibility to provide appropriate protection. Another employer in the present study expressed reluctance to take responsibility for the sun protection of their workers, with many believing that it is the responsibility of the individual. This suggests that higher level policy changes may be necessary to induce protective action. One potential strategy would be for the Health and Safety in Employment Act to be strengthened and more rigorously enforced. Initial opposition would be likely to decline as it became the norm to provide sun safety equipment, like existing provision of other workplace safety products, such as safety helmets, steel-capped boots and eye protection.

When interpreting the study results, some caveats need to be borne in mind. For logistical reasons, workplaces were the principal sampling frame for the study and the sample was not randomly selected and representative of the NZ population of outdoor workers, although this should not affect the observed relations between measured UVR exposure and the occupations studied. Some workplaces did not respond to the letter of invitation to the study, thus potentially introducing bias. The characteristics of participating workplaces and workers may differ (potentially more protective) from those of non-participating workplaces and workers, and may not generalize to all NZ builders, horticulture workers and road workers. Nevertheless, within consenting workplaces, no workers declined to participate. More workplaces were included from the building industry than from road or horticulture, so direct comparisons must be made with caution. Measuring UVR exposure and sun protective practices for five consecutive days is likely to have mitigated any influence of lack of blinding to broad study objectives and/or weather effects, leading to more reliable estimates of typical behaviour. Ambient UVR data were obtained to facilitate comparisons both within the study and with other studies, by permitting the calculation of personal exposure as a percentage of the available ambient UVR and thus reducing seasonal and weather effects.

The objective of this paper was to identify the impact of behaviour and work conditions on UVR exposure. It appears that seeking shade at lunch time leads to decreased exposure for some workers. However, work tasks involving substantial sun exposure do occur within the high UVR period, particularly between 1400 h and 1500 h, thereby adding to the daily exposure burden. To reduce their occupational solar UVR exposure, workers need to make the most of shade opportunities at lunch time, and postpone high-exposure jobs until late afternoon.

Acknowledgements

The authors are grateful for the contributions made by the participating workplaces and workers, without whom the study would not have been possible. The authors would also like to thank staff at the National Institute of Water & Atmospheric Research, Lauder, New Zealand for their expertise and assistance in calibrating the UVR dosimeters.

Ethical approval

Human Ethics Committee, University of Otago, Dunedin, New Zealand (No. 06/138).

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Competing interests

None declared.

References


