

Personal exposures to UV radiation in New Zealand

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Abstract. As part of a study of ultraviolet (UV) radiation exposure and vitamin D status, personal exposure to solar erythemal UV has been measured for periods of 8 or 10 weeks on 517 participants using UV dosimeter badges. Calibration of these badges against data from a Robertson-Berger meter at Lauder gave RMS error within 0.5 UVI. Worn on the wrist, the badges logged exposure every 8 seconds from 06:00 to 22:00, yielding 7200 measures per day or 40,000 – 50,000 per participant for the 8 or 10 weeks. A variety of errors, whether human or electronic, had to be corrected in the combined data set. After removal of erroneous data and filling the resultant and other gaps, a homogeneous data set was obtained, and integrals for three periods per day were combined with clothing survey results to assess total exposure doses. The combined data set contains a wealth of data about participant sun exposure over the course of the two years.

Dosimeter badges

Personal UV dosimeter badges as described by Allen & McKenzie (2010) were worn by 517 participants in a study of vitamin D production by UV radiation in 2008 and 2009. Over the summer months before, between, and after the study periods in 2008 and 2009, the badges were calibrated against a Robertson-Berger meter (Yankee Environmental Systems UVB-1 measuring CIE erythemal UV), traceable via Lauder UV spectrometers and FEL lamps to NIST. Example results are shown in Fig 1. The relationship of badge counts to UVI is nearly linear, but a quadratic term is also used to improve the fit. The badge configuration allows for any offset of the zero, so all fits were constrained to pass through the origin (zero UVI at zero badge counts). The root-mean-square (RMS) residuals from these fits are around 0.2 for clear skies as in Fig 1, but up to 0.75 when broken cloud cover causes very irregular irradiance. The effect may be similar to changing badge orientation in use, so we estimate RMS error in badge data to be about 0.5 UVI.

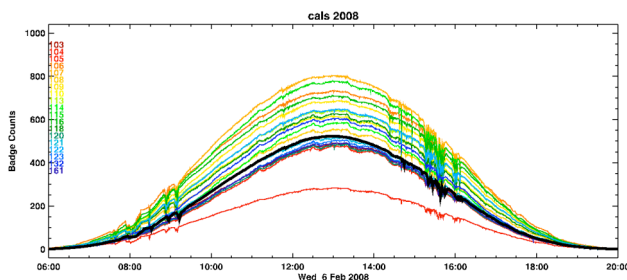


Figure 1. Calibration of dosimeter badges at Lauder on 6 Feb 2008, against YES UVB-1 instrument, shown as a black curve with 20 counts per UVI unit, the average over all badges.

The calibrated badges give a direct measure of irradiance as UVI. Badges were worn on the wrist to minimise inconvenience for participants. Measurements every 8 seconds from 06:00 to 22:00 give 7200 values per day, or 50,400 in a completed week, as illustrated in Fig 2. Values change rapidly with movement in or out of shade, including self-shading with orientation, so hourly means give a better idea of total exposure. Note that one hour's exposure to UVI = 1 gives 0.9 SED (Standard Erythemal Dose = 100 J m⁻² erythemally-weighted UV).

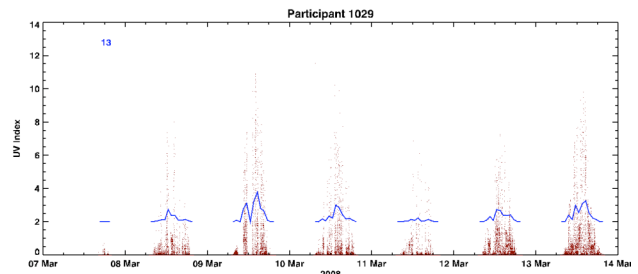


Figure 2. Example time series of daily UVI exposure for an outdoor worker in Auckland. Hourly means, shown in blue, are offset by 2 UVI for clarity.

UV-vitamin D study data

Participants wore the badges for 8 or 10 weeks, so a full data set is around 500,000 values per participant. Inevitably, there were some problems, from badge malfunction or other causes, but completed data series were needed to obtain integrated exposure over time. Figure 3 shows the full record for the above participant.

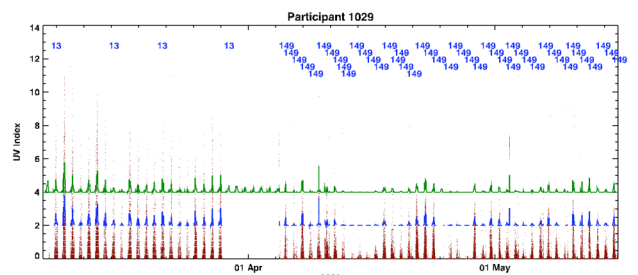


Figure 3. Initial data (dark red), hourly averages (+2 UVI, blue), and completed hourly series (+4 UVI, green).

Correction and gap filling was in two stages, described in more detail in another paper (Liley & Liley 2010). An initial pass through all data for a given badge identified badge faults, including instances where earlier data (resident in badge memory) were incorrectly associated with a new deployment. After identification of all bad data by badge number, processing was by participant. Using a range of measures for each participant (average for that hour of the day, or day of the week, etc.) and other

participants in the same area and time, a perceptron evolved linear estimates from the 10 parameters to fill the data gaps, as in Fig 3. Uncertainties in estimates are derived as part of the perceptron evolution

As noted, modelling UV efficacy in producing vitamin D will require the completed data series, but here we examine features of just the actual measurements. Figure 4 shows all data for Auckland (336 participants) and Dunedin (181). Note the logarithmic scale, and that only upper percentiles appear.

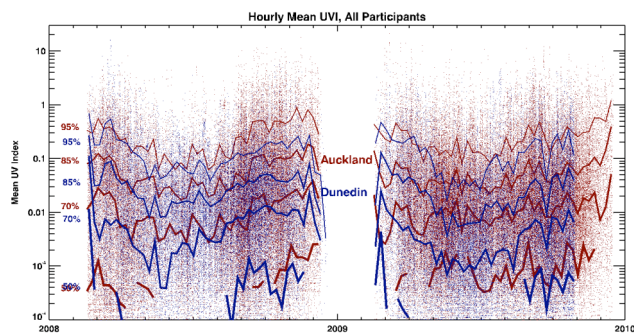


Figure 4. Hourly mean UVI for all participants in Auckland and Dunedin, with percentiles as shown.

Even in summer, 50% of participants had average exposure below 0.001 UVI during daylight hours, 10,000 times less than the daily peak. The comparison with the available UVI in each hour for that region, as obtained from the UV Atlas, is shown in Fig 5.

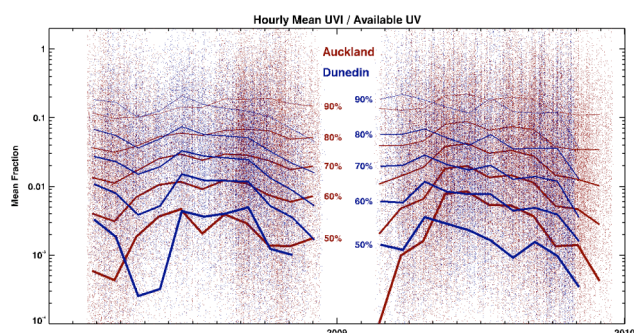


Figure 5. Hourly mean UVI for all participants in Auckland and Dunedin, as a fraction of UVI from the UV Atlas, with percentiles as shown.

Again it is apparent that in any hour only 10% of the participants received more than 10% of available radiation, and for the great majority the figure was much lower. The slight increase in winter months relative to spring and autumn could be a consequence of average sun angles, behaviour, or some other aspect of the measurement process, but warrants further analysis.

The weekly pattern of exposure is shown in Fig 6. Because it does not use a logarithmic scale, only the highest percentiles are shown, but again illustrate that fewer than 5% are exposed to an average UVI of 1 during the midday peak outside the summer months. The diurnal variation is as expected, and Dunedin participants have less exposure than Auckland participants, though the weekend effect is more visible in the Dunedin data.

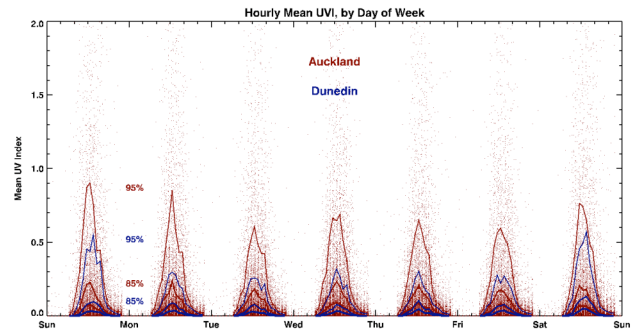


Figure 6. Hourly mean UVI for all participants in Auckland and Dunedin, over all seasons of the study, by day of the week.

Clothing data

To relate received UV to cutaneous production of vitamin D, further information was required. Participants kept a log of clothing worn for three periods of the day; before 11:00, 11:00 to 16:00, and after 16:00. In the summer months, about 70% of daily erythemal UV occurs in the 11:00-16:00 period, and in winter up to 90% is. If summer clothing exposes arms and legs, especially around solar noon, that will accentuate the seasonal differences. The hourly personal exposure data have been aligned with the clothing data to facilitate analysis of such patterns.

A further seasonal difference occurs in the spectrum of UV at Earth's surface. As the sun's elevation reduces, the longer average light path through stratospheric ozone reduces radiation at shorter wavelengths by a greater amount; the ratio of UVB to UVA falls, for example. To examine what effect this may have, the badge data can be scaled by ratios of vitamin D production to erythemal induction for given solar zenith angle and ozone column. Questions about badge response or how well it describes body exposure can be circumvented by using the data just as a binary index of UV exposure, combined with known spectra for sunlight and sunbeds.

Conclusions

Deploying 100 dosimeter badges on 517 volunteers for 8 to 10 weeks has produced a vast amount of UV and ancillary data. This was an epic achievement by Debbie Raroa, Carol Taylor, Vanessa Hammond, Jan Jopson, and Kenneth Gibbs, resulting in over 250,000,000 instantaneous measures of UV exposure. A range of problems arose with badges, data downloads, and human errors, but the volume of good data supports the derivation of meaningful totals.

Further work to disaggregate these data by age, skin type, physical characteristics, work, lifestyle, diet, etc., and relate them to serum 25OHD will follow from here.

References

- Allen, M.W., McKenzie, R.L. 2010. Electronic UV dosimeters for research and education. Paper 11 at NIWA UV Workshop, Queenstown, 7-9 April.
- Liley, A.J., Liley, J.B. 2010. Analysis of dosimeter badge data. Poster 44 at NIWA UV Workshop, Queenstown, 7-9 April.