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UV radiation and its effects

– an update 2010

Report of the NIWA UV Workshop
Queenstown, 7–9 May 2010

Organising Committee

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Assoc. Prof. Robert Scragg, University of Auckland (Co-convenor)
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Posters

UV Workshop Overview

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Abstract. The aims and outcomes of the NIWA UV Workshop, held in Queenstown, New Zealand from 7 to 9 May 2010 are briefly discussed.

Introduction

UV radiation is by nature a crossroads between many disciplines, including atmospheric chemistry and physics, botany, zoology, materials science, health. policy, manufacturing, and education. Health promoters and the media also have an interest in UV radiation and its effects. Consequently, progress requires a multidisciplinary approach, but these diverse groups rarely have a chance to interact.

The aim of the NIWA UV Workshop was to provide a forum for discussion among groups involved with all aspects of the causes and effects of changes in UV radiation. The workshop included panel discussions to identify future needs for research, policy advice, and health promotion in this area. It was organised along similar lines to the successful UV workshops held previously in 1993, 1997, 2002, and 2006, which were sponsored by the Royal Society of New Zealand, the National Science Strategy Committee on Climate Change, and the Cancer Society of New Zealand.

The range of possible topics included:

- UVR Variability and Causes
  - Ozone depletion in New Zealand
  - Cloud and aerosol effects
  - Relationship between ozone depletion and global warming
  - Future trends in ozone/UV
  - UVR in New Zealand, and relationship to other locations
- UVR Impacts on Human Health (both positive and negative)
  - Risks of excessive UVR (including skin cancer)
  - Risks of insufficient UVR (including insufficient vitamin D)
  - Dissemination of UVR information to the public
    - the ultraviolet index
    - balancing the risks and benefits of sun exposure
- UVR Impacts on Plants/Animals/Physical environment
  - Terrestrial plants and animals
  - Aquatic Plants and Animals (oceans and freshwater)
  - Ecosystems
  - Materials (e.g., paint, plastics, textiles)
  - Biogeochemical cycles
- Atmospheric Chemistry

Papers were presented at the Workshop on most of these topics. Unfortunately, no papers were presented on UV damage to materials (e.g., building plastics, paints), despite this being an important issue in New Zealand.

The New Zealand context

The main emphasis was on the New Zealand /Australia region, which has unique problems associated with UV radiation. Previous studies have shown that New Zealand's peak sunburning UV irradiances are not particularly high in a global context. The peak UV index (UVI) is approximately 13 in New Zealand compared with peak values of 25 in the Altiplano region of Peru. Peak UVI values are higher than in New Zealand over more than half of the planet, and for close to 90% of the global population. However, our UVI values are relatively high for fair-skinned populations. Measurements of peak UVI values from the Lauder site (45°S, 170°E, alt 370 m) are approximately 40% more than at corresponding latitudes in the Northern Hemisphere (McKenzie et al. 2006). Mean UV values too are much higher than at comparable latitudes in Europe for example.(Seckmeyer et al. 2008) These hemispheric differences are attributable to seasonal changes in Sun-Earth separation (a 7% effect), lower ozone amounts and cleaner atmosphere.

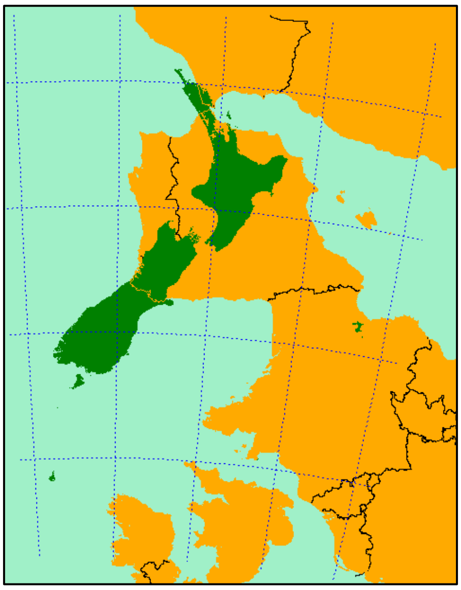

Figure 1. Map of New Zealand superimposed on its inverted antipodes (mainly Spain). Note that the latitudes of the UK are much higher, and that the north of New Zealand is at the same latitude as North Africa.

New Zealand and Australia share the dubious honour of having the world's highest mortality rates for melanoma. The high UVI values in the southern hemisphere compared with the northern hemisphere at the corresponding latitudes are undoubtedly a contributing factor. Furthermore, many New Zealanders and Australians are descended from the British Isles, which are located at a much higher northern latitude (see Figure 1), where UVI values are much lower, and where one would expect the population to be less well adapted to high UV irradiances. In the British Isles the UVI rarely exceeds 8. Other factors include the outdoor lifestyle of many New Zealanders, and the relatively low air temperatures which are conducive to sun bathing. UV irradiances in New Zealand are significantly lower than in Australia, so it remains a puzzle why the skin cancer rates should be so similar. Possible candidates are: better education and darker skin tones, since a larger proportion of the European population in Australia are from Southern Europe. Higher temperatures in Australia may also be important, as they discourage exposure to direct sunlight. However, there are indications of linkages between increasing UV, increasing temperature and increasing rates of skin cancer in Australia.

Themes

A recurrent theme throughout the workshop was the dichotomy between the harmful effects of UV radiation: (e.g., from sunburn and skin cancer), compared with the beneficial health effects through the production of vitamin D (McKenzie et al. 2009). Because of the success of the Montreal Protocol on protection of the ozone layer, we have probably now passed the period where UV irradiances are highest. However, even after a full recovery of the ozone layer, which is now expected late in the century (UNEP 2010), summertime UV irradiances in New Zealand will remain high compared with those at corresponding latitudes in the northern hemisphere. Thus, protection against the damaging effects of summertime UV will be required for the foreseeable future. On the other hand, winter UV amounts are already very low, especially in the south of the country, and contribute to the low vitamin D status of many New Zealanders. These winter values may decrease further in the future as ozone recovers and the effects cloud cover and aerosols respond to climate change. Thus the problem of low vitamin D status in winter may become worse, especially if the trend toward indoor living continues.

A direct result of the previous UV Workshop, in 2006, was the setting up of a collaborative project between researchers at NIWA and the Universities of Auckland, Otago, and Canterbury, to investigate the relationship between UV radiation and vitamin D status among the New Zealand population. The project is funded by New Zealand's Health Research Council (HRC), and preliminary results from it were presented in several papers. Some of this new research involved the use of newly developed electronic personal UV dosimeter badges. These were invented in New Zealand, and are now becoming widely sought after in other international studies. There were also several papers discussing UV radiation and its health effects from sunbeds.

The latter stages of the workshop discussed the effects of UV radiation on human health, with a strong focus on how to best convey UV information to the public to optimise health outcomes ir both New Zealand and Australia.

Concluding remarks

As with the previous two UV Workshops, PDF versions of the papers presented are freely available on NIWA's internet site (http://www.niwa.co.nz/our-services/online-services/uv-and-ozone/workshops). A detailed summary of the workshop highlights and its outcomes is in preparation at the time of writing, and will be published elsewhere (McKenzie et al., submitted). Already there are new collaborative projects flowing on from the contacts made at the workshop.

I would like to close by thanking everybody involved for making the event a success. Firstly, the sponsors: NIWA, the Royal Society of New Zealand, The Cancer Society, the Health Sponsorship Council (SunSmart), and The Department of Health. Secondly, a big thank you to my co-convenors: Assistant Prof. Dr Robert Scragg (University of Auckland), Dr Judith Galtry (Cancer Society), and Graeme Strang (NIWA). Finally, I'd like to thank all of the participants for their contributions. I look forward to meeting again at the next UV Workshop.

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Ozone: past, present and future

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Abstract. Over the past 50 years the global ozone layer has been depleted by anthropogenic emissions of ozone depleting substances. This paper presents an overview of the changes observed in global ozone to date, addresses the effectiveness of the Montreal Protocol in reversing the decline in ozone, and describes projections in future ozone and their dependence on changes in climate. While the primary focus of the paper is on ozone, potential avenues for future UV research, and the likely importance of future UV changes in the tropics, are also discussed. The paper concludes with an outlook on potential future threats to the ozone layer; in particular geoengineering.

Global ozone mass

Daily global total column ozone fields from the NIWA combined total column ozone database have been used to calculate daily global ozone mass values (Figure 1). A clear annual cycle in global ozone mass is apparent. Global ozone mass increases during the first 4 months of the year as ozone is transported to Arctic latitudes where its lifetime is long. As the sun returns to the Arctic and the northern hemisphere meridional transport weakens, global ozone mass falls. The Antarctic polar vortex, which is significantly stronger than the Arctic vortex, creates a stronger barrier to meridional transport so that ozone is not transported efficiently to Antarctic latitudes. This, together with the effects of the Antarctic ozone hole, suppresses a second peak in global ozone mass during the southern hemisphere winter and spring.

Figure 1 also shows anomalies in global ozone mass which approximately mirror the changes in stratospheric halogen loading (not shown). Global ozone decreases from the beginning of the record, showing significant declines after the two largest volcanic eruptions in the period (orange arrows in lower panel), and reaching a minimum in 1993, two years after the eruption of Mt Pinatubo. Thereafter, ozone shows a steady increase with a rapid rise to levels close to what was observed from 1979 to 1981 by the end of the period. Whether this recent increase is sustained will require a few additional years of measurements.

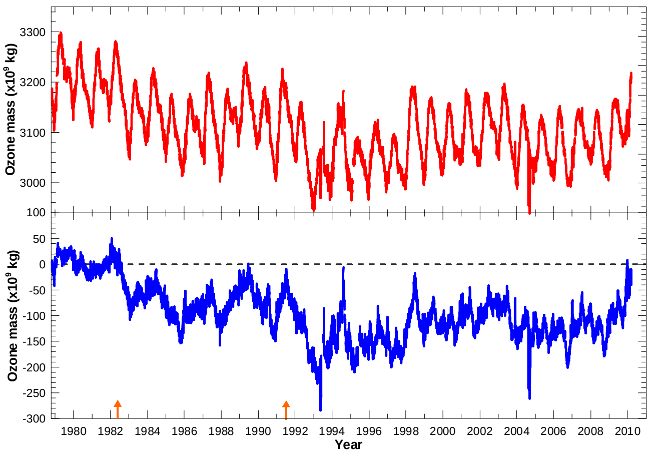

Figure 1. Upper panel: daily global ozone mass from November 1978 to March 2010. Lower panel: global ozone mass anomalies with respect to the 1979–1981 mean annual cycle. The two orange arrows denote the timing of the El Chichón (April 1982) and Mt Pinatubo (June 1991) volcanic eruptions.

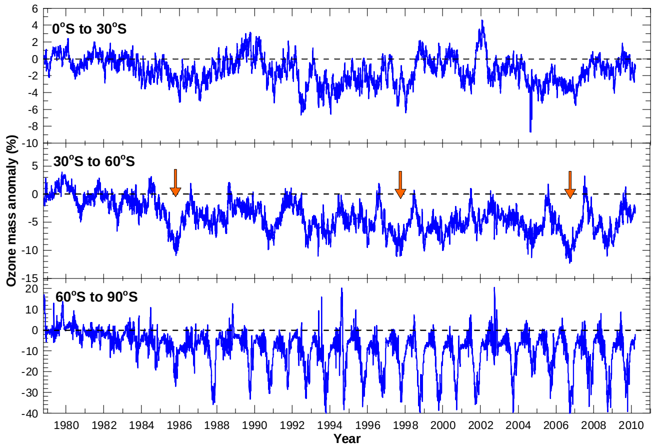

Figure 2. Daily ozone mass percentage anomalies (with respect to 1979-1981) for 30° latitude zones in the southern hemisphere. The orange arrows indicate periods of excessively low southern midlatitude ozone (see text for details).

Ozone mass percentage anomaly time series in 30° latitudes zones for the southern hemisphere are shown in Figure 2. The low latitudes of the southern hemisphere show only small reductions in ozone. Mid-latitudes show a more pronounced decline punctuated by periods of excessively low ozone (orange arrows in Figure 2). These events result from a combination of (i) an anomaly in the meridional circulation resulting from the westerly phase of the equatorial quasi-biennial oscillation (QBO), (ii) weaker transport of ozone from its tropical mid-stratosphere source across the subtropical barrier to mid-latitudes related to the particular phasing of the QBO with respect to the annual cycle, and (iii) a solar cycle induced reduction in ozone (Bodeker et al. 2007). These events highlight the importance of tropical processes for ozone over southern mid-latitudes and in particular indicate that any future changes in the tropical source of ozone could affect southern mid-latitude ozone. Figure 2 also shows the development of the Antarctic ozone hole with large negative ozone anomalies appearing in late winter and early spring from the mid 1980s onwards.

The effectiveness of the Montreal Protocol

In 1985 the *Vienna Convention for the Protection of the Ozone Layer* was signed by 20 nations who agreed to take appropriate measures to protect the ozone layer from human activities. In 1987, in response to growing concern, the *Montreal Protocol on Substances that Deplete the Ozone Layer* was signed, and entered into force in 1989. As scientific advances led to deeper understanding of the chemical processes affecting ozone, and the implications of those changes, a number of Amendments and Adjustments were enacted to provide further protection of the ozone layer (Figure 3).

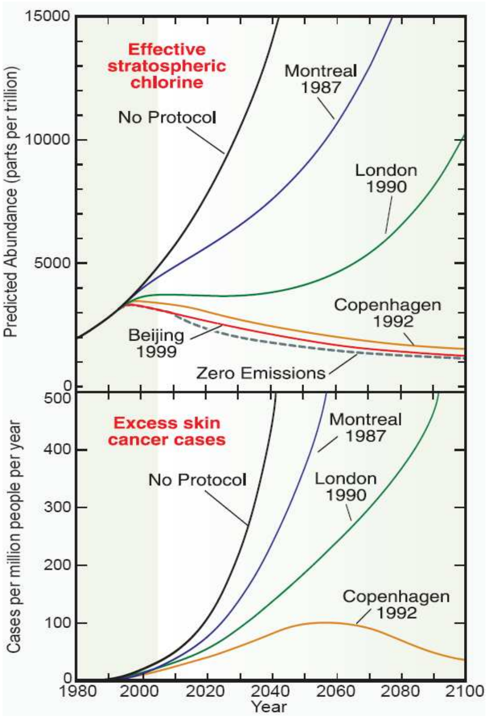

Figure 3. Projections of future abundances of effective stratospheric chlorine (a combination of the effects of chlorine and bromine on stratospheric ozone) are shown in the top panel assuming (1) no Protocol regulations, (2) only the regulations in the original 1987 Montreal Protocol, and (3) additional regulations from the subsequent Amendments and Adjustments. The lower panel shows how excess skin cancer cases might increase with no regulation and how they might be reduced under the Protocol.

In response to the provisions of the Protocol, ozone through much of the atmosphere is no longer declining and in some regions ozone is increasing. In some cases the increase has been driven by changes in dynamics possibly brought about by changes in climate. To assess the success of the Montreal Protocol, it is therefore important to correctly attribute the causes of observed changes in ozone. Chemistry-climate model projections indicate that were it not for the Protocol, 17% of the global ozone mass would be destroyed by 2020, and 67% destroyed by 2065 compared to 1980 values. Ozone in the tropical lower stratosphere would collapse to near zero around the middle of

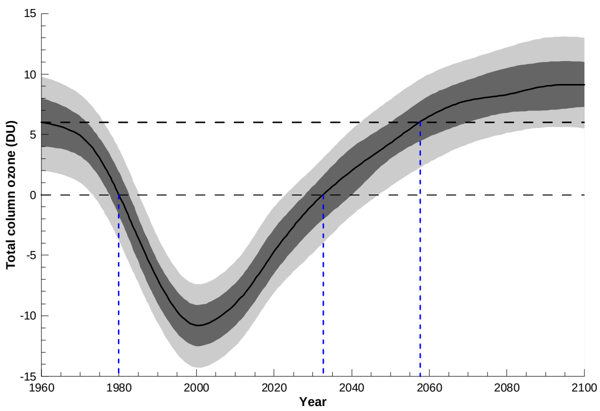

Figure 4. Annual mean global total column ozone chemistry-climate model simulations. The thick black line shows the multi-model mean and the dark- and light grey shaded regions show the 95% confidence and 95% prediction intervals, respectively. The horizontal dashed lines show 1960 and 1980 levels while the vertical dashed lines indicate dates of return to those levels.

the century as a result of heterogeneous chemical processes (as currently observed in the Antarctic ozone hole, see paper by Wood et al., this volume). The summer-time UV index would exceed 25 over midlatitudes during the latter half of the century.

Future projections and interactions with climate

Projections of global ozone changes through the 21st century from a suite of chemistry-climate models are shown in Figure 4. Global mean ozone is projected to return to 1980 values sometime during the 2030s and to 1960 values in the 2050s. Later in the century global mean ozone is projected to be higher than 1960 levels. This results from greenhouse gas induced cooling of the upper stratosphere which slows gas phase ozone destruction chemistry. However, the same increase in greenhouse gases induces changes in stratospheric transport. In the tropics this decreases ozone in the lower stratosphere so that during the latter half of the 21st century, tropical total column ozone is projected to be in decline.

There are other potential future threats to tropical ozone. Proposals for large scale kelp farms as a means of CO_2 sequestration would increase marine biogenic emissions of bromocarbons. This, together with increases in sea-surface temperatures (which also increase bromocarbon emissions) and increasing strength and ubiquity of tropical deep convection, would increase the flux of bromine to the tropical lower stratosphere. This would induce additional ozone depletion in the tropical and extra-tropical lower stratosphere which would in turn increase surface UV irradiance. Higher UV stresses kelp and induces higher bromocarbon emissions. The potential effects of this positive feedback biogeochemical cycle have not yet been quantified.

Geoengineering

As a means of mitigating the effects of increases in greenhouse gases on surface temperatures, serious consideration is being given to combating climate change through geoengineering. The most technically feasible approach would be continuous emissions of sulphate to the stratosphere at ~2 Mt/year. In the stratosphere the sulphate is oxidised to form sulphuric acid aerosols which reflect incoming solar radiation. This would be equivalent to 'perpetual post-Pinatubo' conditions; the Mt Pinatubo volcanic eruption cooled global surface mean temperatures for a few years after the eruption. However, it is clear from Figure 1 that large enhancements in stratospheric sulphate aerosol loading significantly reduce ozone. Under such a scenario, the recovery of the Antarctic ozone hole could be delayed by between 30 and 70 years depending on the assumed geoengineered aerosol size distribution. Therefore, during the period when stratospheric halogen levels remain elevated, implications of sulphate geoengineering on stratospheric ozone need to be carefully considered as part of climate change mitigation policy employing this approach.

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The Antarctic Ozone Hole: Didn't we fix that already?

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Abstract. The Antarctic ozone hole, a rapid depletion of ozone that occurs each spring over Antarctica, first formed more than 30 years ago. When discovered, it prompted international action, firstly to understand the mechanisms by which it formed, and then to control the production and use of ozone depleting chemicals, resulting in the Montreal Protocol and its subsequent amendments. This action appears to have been successful, and serves as a model of the way that other global environmental issues could be addressed. Continued monitoring of the ozone hole is important to assess whether the continued "recovery", or lessening in the severity, of the ozone hole is occurring as expected, and to check our understanding of the processes and feedbacks involved.

Atmospheric scientists have often had to explain that ozone depletion and the resulting changes in ultraviolet radiation at the Earth's surface are not the same as the main issue of climate change, which is that increasing concentrations of some gases in the atmosphere that are altering the balance of long-wave or infrared radiation in the atmosphere, referred to as "greenhouse" gases, are producing a warming at the Earth's surface. However, as both ozone changes and greenhouse gas changes are composition changes that affect the chemistry, the temperature profile and the circulation in the atmosphere, there will be potential couplings between them.

Why in Antarctica?

The ozone hole arises from a combination of factors that occur in the Antarctic region.

- Isolation of the atmosphere over Antarctica caused by a meteorology pattern known as the polar vortex – a band of strong westerly winds that forms over winter around Antarctica and limits air exchange between inside and outside the vortex.
- A lack of incoming solar radiation in the polar night, in combination with the vortex, results in very low stratospheric temperatures (Figure 1)
- The temperatures are low enough for formation of polar stratospheric clouds (PSCs), made up of particles of frozen hydrates of nitric acid (HNO_3) or water ice.
- The surfaces of these particles provide reaction surfaces for the conversion of anthropogenic chlorine and bromine in the stratosphere into more chemically active forms.
- As sunlight returns in spring, the last step in this activation occurs by photolysis of chlorine and bromine
- The activated chlorine and bromine react with ozone and are replenished in catalytic cycles, causing rapid ozone loss. (Figure 2)
- Even after the chemical conversion has stopped, low values of ozone are maintained within the polar vortex until the vortex dissipates or breaks up.

This combination of conditions is unique to the Antarctic. The Arctic does experience sufficient low temperatures, PSC formation and consequent ozone depletion, but these conditions do not last long.

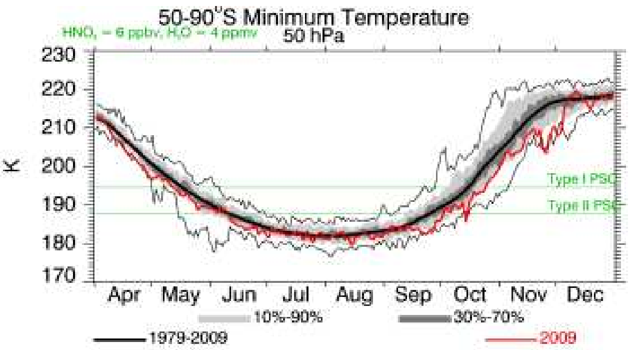

Figure 1. Minimum temperature measured poleward of 50° S at 50 hPa (~20 km altitude) showing the low temperature conditions for the formation of the ozone hole. Marked with green lines are the temperatures at which two different sorts of PSCs form for typical concentrations of nitric acid and water vapour.

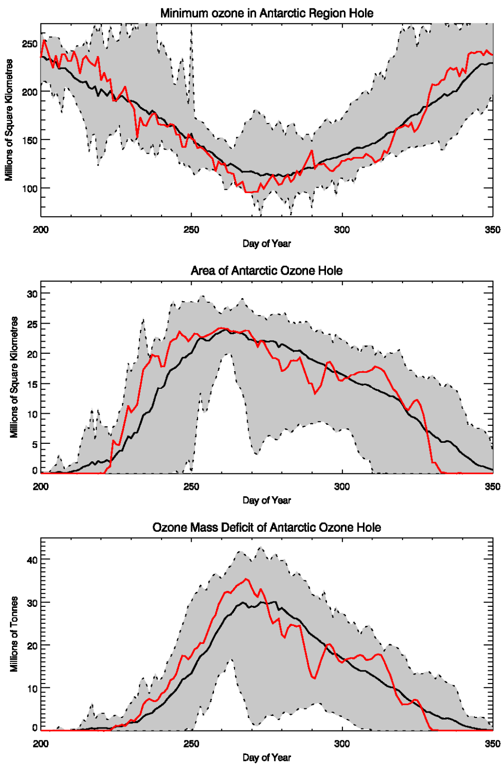

Figure 2. The minimum ozone, area and ozone depleted mass for the 2009 ozone hole (red lines) plotted against the means (black line) and extreme values (grey shaded area) for 1990–2009. The hole area is defined as the area

where total ozone is less than 220 Dobson units (1000 DU = 1 atmosphere-centimetre) and the mass deficit is the amount of ozone required to bring the total ozone up to 220 DU over the whole ozone hole area.

The Montreal Protocol

The protocol to limit the production of ozone depletion substances has resulted in the level of anthropogenic chlorine and bromine in the atmosphere beginning to decrease. For details see Figure 3 and discussion in the preceding paper by G. Bodeker. Without the protocol, ozone depletion would have continued unchecked. It is now predicted that the ozone hole will slowly recover, and this has begun to be observed (Figure 3). Full recovery is still expected to take several decades.

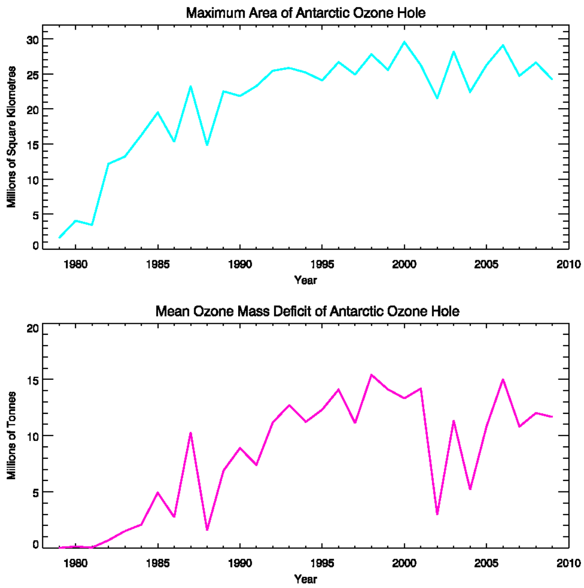

Figure 3. Top plot: the maximum area of each year's ozone hole, defined as for Figure 2. The areas grew rapidly during the 1980s and 1990s but have now levelled off. The large year to year variations are due to variations in meteorology. Bottom plot: the ozone mass deficit of each hole averaged over the period mid July to late December each year. Apart from unusual years in 2002 and 2004, this measure more clearly shows a recovery in ozone hole severity.

Interaction of the ozone hole with mid-latitudes

Ironically, when the ozone hole is at its maximum extent in spring, southern mid-latitudes experience the highest amounts of ozone of their annual cycle (Figure 4). The effect of the ozone hole is felt later in the year when the polar vortex, and hence the ozone hole, breaks up. Up until that point the hole may move around in a sloshy, rotating motion that may distort the area into elongated shapes, driven by planetary scale wave motions. When the hole does break up the effect is to dilute the ozone in the region around Antarctica. Hence mid-latitude regions experience their lowest ozone values in the mid to late summer.

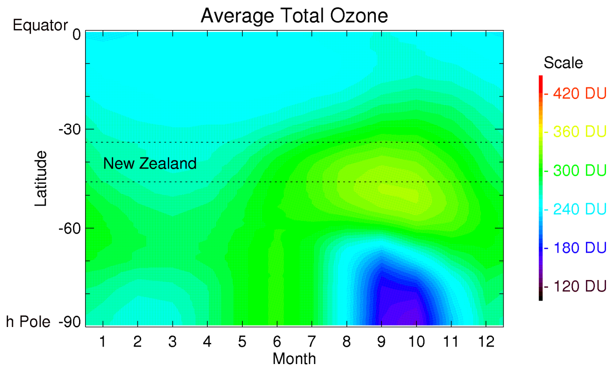

Figure 4. Average zonal total ozone in the southern hemisphere. At the time of the ozone hole many places at mid-latitudes have their maximum seasonal ozone. It is later in the summer that minimum ozone values occur at these places.

Ozone and climate change

Climate and atmospheric circulation are important influences on ozone, as illustrated by the mix of dynamical and chemical factors contributing to the ozone hole. However, ozone is an important driver of atmospheric circulation and climate as it is the principal source of heating in the stratosphere. There are significant interactions between the two. For example, the ozone hole is thought to have contributed to the strong contrast between the observed temperature trends over the bulk of Antarctica which have been very nearly flat, and those slightly further north over the Antarctic Peninsula, one of the fastest warming regions on the planet. There may still be surprises and influences we don't understand

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Developing UV monitoring with CCD technology

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Abstract. Two instruments for monitoring UV irradiance using single monochromator charge-couple detector (CCD) array detectors have been developed for use within the Bureau of Meteorology's (BoM) Solar and Terrestrial Monitoring Network. The BoM has had some success in using CCD array detectors for monitoring direct solar spectral irradiance at visible and near infra red irradiance but the move to monitor UV required solving several significant issues, particularly the rapid rate of change in UV irradiance with wavelength and the strong stray light conditions typical of single monochromators. Two types of instruments were developed: a direct irradiance spectrometer (ASR-UV) and a 2π sr radiometer (Pi-radiometer) for monitoring global and diffuse solar spectral irradiance. The instruments will be deployed in test phase in April 2010. The rationale for the basic design will be described as will the methods utilised to minimise the limitations of the use of a single monochromators and CCD technology.

Rationale

The BoM maintains a five station network of Dobson spectrophotometers for monitoring total column ozone: these instruments are manually operated and began operation at the time of the International Polar Year in 1957. The BoM also operates a three station network of UV spectrometers: two based on the NIWA (McKenzie et. al. 1992; Bernhard et al. 2008) design at Alice Springs and Melbourne and one Optronics 704 system at Cape Grim. The only solar erythemal UV monitored by the BoM is also at Cape Grim.

Dobson spectrophotometers in the BoM network collect data between 3 and 4 times per day centred on solar noon, with the most accurate data provided by direct solar measurements; spectrophotometers measure ratios of irradiance and hence are not capable of monitoring spectral irradiance. The Dobson spectrophotometers are now over 60 years old and the expertise to maintain them is difficult to develop. Other spectrometers using scanning double monochromators for monitoring direct and global UV and hence deriving ozone exist but are expensive both in initial cost and on-going maintenance.

In 2000 the BoM designed and deployed two direct spectral irradiance radiometers (ASR) utilising small dual CCD array detectors with a spectral resolution of about 1.1 nm over the range 360–1000 nm. The devices enable traceability of the spectral irradiance to the World Radiometric Reference with a typical 95% uncertainty of 2% when the direct solar irradiance was greater than 700 Wm^{-2}, and are used for monitoring spectral transmission and deriving aerosol optical depth. The CCDs used in the instruments proved to be very stable with no change in sensitivity (at 25 °C) in 10 years of operation.

While stable, these initial CCDs had characteristics that had to be determined before successful measurements could be attempted. The main characteristics apart from sensitivity were: (a) the zero signal was dependent on temperature and unique for each pixel; (b) the sensitivity of each pixel to solar exposure had a unique temperature coefficient; (c) the range of wavelengths meant that an order sorting system was required; (d) the detectors are non-linear; (e) there was a small shift in wavelength as a function of temperature; (f) stray light; and (g) dynamic range was limited.

However, since 2000 the development of CCD spectrometers continued with improvements in grating and detector combinations, including at UV wavelengths, and filter technologies developed for LASER applications provided scope for stray light minimisation.

As a result, the BoM decided to investigate the use of CCD technology to replace its ageing Dobson spectrometers for monitoring ozone and develop a small compact device for monitoring UV, but with a simple design using as many off-the-shelf components as possible.

Design concept

Two types of radiometer were developed: one modifying the existing ASR system for monitoring direct solar UV spectral irradiance, and another using the NIWA diffuser for monitoring global and diffuse solar UV solar spectral irradiance. The basic layout of the Pi-radiometers can be seen in Figure 1. The ASR differs from the Pi-radiometer by replacing the dual filter wheel with a single filter wheel and fixed UG11 filter that are both in front of the diffuser.

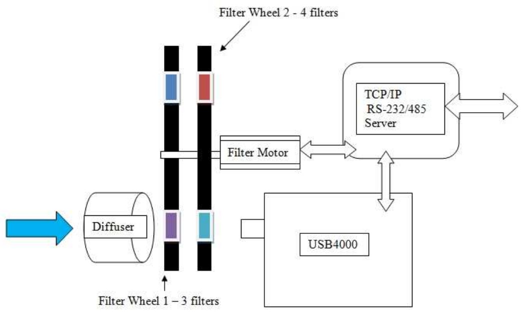

Figure 1. The schematic of the Pi-radiometer indicates that it communicates to the controlling PC via a dual port RS-232/485 interface via TCP/IP, with one port for the stepper motor and temperature monitoring channels and the other for the Ocean Optics[1] USB4000 spectrometer.

The Pi-radiometer's dual filter wheel has 3 filters in the 1st and 4 filters in the 2nd filter wheels allowing 12 potential combinations to isolate parts of the incoming

[1] Naming of the Ocean Optics product does not indicate Bureau of Meteorology endorsement.

spectrum and to assist with stray light elimination. The ASR single filter wheel has 8 positions for filters. The two radiometers are shown in Figure 2.

Figure 2. On the left is the ASR deployed at Melbourne Airport, and on the right the Pi-radiometer, next to a CD-ROM to provide an indication of size.

Both the Pi-radiometer and ASR-UV configuration use a single Ocean Optics USB4000 UV-enhanced spectrometer with a 3640 pixel detector, a pixel width of 0.072 nm over an effective wavelength range of 265 to 490 nm, and a slit width of 50 µm, providing a typical resolution of 0.5 nm.

The filter position is determined by a high precision stepper motor and position sensing element. Five temperature sensors are deployed to monitor the internal temperatures and those of the diffuser and outside temperature of the USB4000. The USB4000 also has an internal temperature monitor. The Pi-radiometer uses the same diffuser developed for the NIWA spectrometer.

The filter sequence and data acquisition are controlled by PC software using the TCP/IP connection to relay commands and receive data via the BoM wide area network. A full sequence of measurements with all valid filter positions is typically less than 3 minutes in duration.

Resolving technical issues

(a) Zero signal variation with temperature.

There is no need to calculate zero signal levels as zero blocked filter zero irradiance spectra are taken at the start and end of each measurement sequence and subtracted from irradiance spectra.

(b) Changes in sensitivity due to temperature

The spectrometers are placed in a thermal chamber and connected to a constant irradiance source. The spectrometers are then cycled through temperatures between 5 °C and 45 °C at 5 °C increments and the temperature sensitivity for each pixel is determined. The internal temperature of the USB4000 is used as the representative temperature.

(c) Order sorting

The small spectral range (250 nm) of the spectrometers has minimised order sorting issues.

(d) Non-linearity

Each spectrometer is provided with non-linearity coefficients by the manufacturer but these were found to be error prone at low and high count levels. The BoM performs its own non-linearity tests over the range of 200 to 32 000 counts. The non-linearity is typically <2% over the entire range and quadratic in nature.

(e) Wavelength calibration

Laboratory tests have shown small (<0.1 nm) changes in wavelength over a 40 °C range in temperature which can be modelled. However, as with the NIWA spectrometer (McKenzie et. al. 1992) processing the wavelength adjustment of each scan will be undertaken using the structure of the solar output using the Fraunhofer lines.

(f) Stray light

Two methods are to be used to minimise stray light impact. First, the method detailed by Zong et al. (2006) that uses mathematical inversion of LASER line response functions to provide a stray light irradiance corrected signal. The second method uses very sharp cut off LASER edge filters to allow transmission of irradiance at higher wavelengths where the dominant solar energy lies, hence at wavelengths shorter than the cut off, a standard spectrum minus the LASER line spectrum should provide a stray light reduced spectrum. Initial tests suggest that the latter method combined with a UG11 filter that transmits at wavelengths less than 400 nm provides significantly reduced stray light. Initial studies also indicate that a simple correlation with higher wavelength spectral counts (essentially an empirical inversion) may be satisfactory for all wavelengths over 300 nm.

(g) Decadal signal variation over 20 nm

The use of LASER edge filter at wavelengths of 300 and 325 nm and different integration times will enable a combined spectrum to be produced from 3 or more separate measurements. As the increase in spectral irradiance is at longer wavelengths than UV, the collection of saturation free spectra is straightforward and stray light is minimised.

Traceability of the UV measurement is through the use of NIWA compact lamp units that are calibrated on a regular basis.

Future

The ASR UV will be collocated with the Melbourne Dobson spectrophotometer in early April 2010, and the UV Pi-radiometer collocated with the existing NIWA UV spectrometer at a Bureau test facility, also in Melbourne. Four more UV Pi-spectrometer should be deployed in 2011. Adaption to a solar tracker will enable alternate global and diffuse measurements (Wilson & Forgan 1996).

The Pi-radiometer can also be configured for 350–1000 nm observations and one is expected to be deployed at the Alice Springs station in late 2011.

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Spectral measurements of solar UV at several altitudes under Australian conditions

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Abstract. ARPANSA maintains a network of broadband solar UV dataloggers in major Australian population centres, all of which are currently at or near sea level. However, solar UV levels are known to increase with altitude (Blumthaler et al. 1997, McKenzie et al. 2001). Most previous studies on the altitude effect have been conducted in the northern hemisphere and to our knowledge no spectral investigation has been completed under Australian conditions. ARPANSA is currently undertaking an investigation of the effects of altitude on the measured solar UV spectrum at various sites in the state of Victoria, Australia. Results from this study will be used to help validate the models used for the Cancer Council's SunSmart UV Alert programme.

Introduction

The broadband solar UV network operated by ARPANSA currently operates in nine locations around Australia (Figure 1). Data from the network are posted in near real time (updated once a minute) on the ARPANSA website.

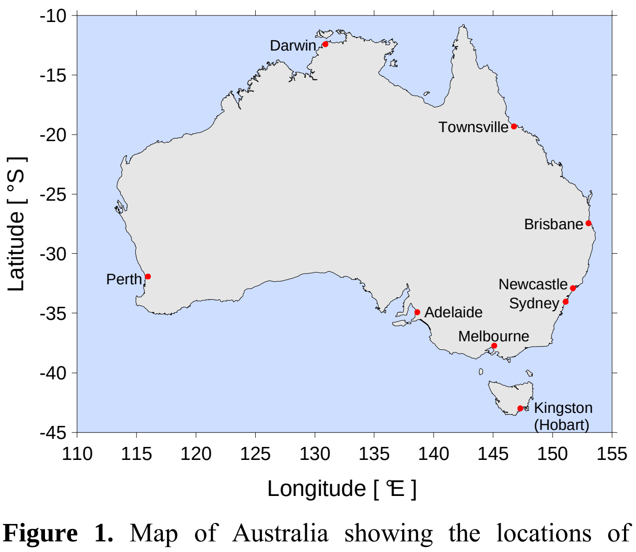

Figure 1. Map of Australia showing the locations of ARPANSA's broadband UVB detectors.

The solar UV spectrum has been measured periodically by various groups at a number of sites in Australia including the Bureau of Meteorology (BoM) at Darwin (altitude 31 m), Alice Springs (547 m) (Kalashnikova et al. 2007) and Cape Grim (94 m), the University of Southern Queensland at Toowoomba (693 m) (Parisi et al. 2003) and James Cook University at Townsville (30 m) (Bernhard et al. 1997).

Since late 2008 ARPANSA has also been routinely recording solar UV spectra each day from its laboratory in Yallambie, a suburb about 15 km from the centre of Melbourne.

SunSmart UV Alert

The SunSmart UV Alert programme is a joint initiative of the Cancer Council Australia, the Bureau of Meteorology (BoM), and ARPANSA designed to prompt the public to take sun protection measures whenever the UV Index exceeds 3. It is reported on the weather page of the major Australian newspapers as well as on the BoM website for over 300 locations across the country.

To be useful and relevant the UV Alert must be specific for the region in which it is declared. Sophisticated modelling by the BoM is used to forecast the solar UV for all areas of Australia, but there is little measurement data to support these predictions for locations outside the major metropolitan centres.

Of particular interest to the Cancer Council are the Victorian Alpine areas. Although the resident population is small, significant numbers of tourists visit the area all year round. The generally clear atmospheric conditions combined with higher altitudes mean that UV exposures are likely to be higher than visitors from the city might expect and the potential for UV over-exposure is high.

Instruments and methods

The ARPANSA solar UV network employs broadband UVB detectors (UV Biometer model 501, Solar Light Company, Philadelphia PA, USA). These detectors record erythemally weighted UVB and are calibrated at ARPANSA's laboratory in Yallambie by comparison with a UV spectrometer before deployment at the other sites.

ARPANSA currently operates two identical UV spectrometers (model DTMc300, Bentham Instruments Limited, Reading, UK). Each of these detection systems is composed of a double monochromator with fixed slits giving a 1 nm bandwidth, a cosine-corrected Teflon diffuser, fibre optic light guide and a bi-alkali photomultiplier tube. The spectrometers are irradiance calibrated using a 1 kW tungsten filament lamp traceable to international standards through Australia's National Measurement Institute and wavelength calibrated against the UV spectral lines of a mercury lamp.

One of these systems is installed on the rooftop of the ARPANSA building in Yallambie. The second system is packaged so as to be portable and can be powered by a 12 V battery pack running through a sine-wave inverter.

The portable spectrometer was taken to four sites within a few hours' drive of ARPANSA at various altitudes as indicated in Table 1. Spectra were collected at each of these sites to compare with the data collected by the rooftop system at Yallambie. All measurements were collected during late spring and early summer (October to December) 2009.

A handheld ozone meter (model MicroTOPS II, Solar Light Company, Philadelphia PA, USA) was used to measure the total column ozone at the remote locations.

Table 1. List of measurement locations with distances from ARPANSA, altitudes, range of SZA and the total column ozone amounts from satellite (OMI) and ground based (µTOPS) measurements.

Location	Distance [km]	Altitude [m]	Min SZA [°]	Max SZA [°]	OMI O_3 [DU]	µTOPS O_3 [DU]
Yallambie	0	30	25.0	46.6	313	306
Kinglake	30.5	543	20.7	28.4	315	----
Mt Macedon	60.6	985	14.1	24.9	279	258
Mt Donna-Buang	51.3	1246	19.7	27.8	311	297
Mt Buller	134.3	1720	16.4	33.6	274	258

These measured values were consistently lower (by 2– 8% over the range of locations) than those reported by NASA from the Ozone Monitoring Instrument (OMI). This level of agreement is quite good considering the spatial resolution of the satellite data is about 100 km².

Results and discussion

In order to compare the performance of the two systems the portable spectrometer was operated in the grounds of ARPANSA, 15 m below the rooftop system, in a clear grassed area to the north of the ARPANSA building. Simultaneous measurements were conducted at 10 minute intervals throughout the middle of the day while the sun was well above the surrounding trees.

Spectra from the two instruments agreed well, within ±3% for total UVR. However, the portable spectrometer appears to read consistently lower by 7% in the UVB compared to the rooftop spectrometer.

Measurements at Kinglake were blighted by some passing cloud just after solar noon. Weather conditions at Mt Donna Buang were clear with just a little thin high cloud later in the day, while at Mt Macedon skies were fine all day after some early fog and haze. Measurements at Mt Buller were impaired by less than favourable weather conditions.

Spectral irradiances weighted by the erythema action spectrum (CIE 1987) are shown in Figure 2 for SZA 25°, the smallest SZA common to all sites. The most notable features of these spectra are:

- enhanced UVB due to lower ozone at Mt Macedon
- significantly enhanced UVR for all wavelengths at Mt Donna Buang
- greatly decreased UVR for all wavelengths due to cloud at Mt Buller (despite lower ozone values).

The mean ratio of 25° SZA spectra relative to those measured at Yallambie for UVR (300–400 nm), UVA (315–400 nm) and UVB (300–315 nm) is listed in Table 2. Results from Mt Macedon have been corrected for the lower total column ozone. Excluding the cloud affected results from Mt Buller, an altitude gradient may be obtained by linear regression to the data with the result of

Table 2. Mean ratio of spectral irradiances relative to Yallambie portable spectra at solar zenith angle 25°.

	Kinglake	Mt Macedon	Mt Donna-Buang	Mt Buller
UVR	1.06	1.16	1.27	0.65
UVA	1.06	1.11	1.25	0.63
UVB	1.09	1.25	1.40	0.75

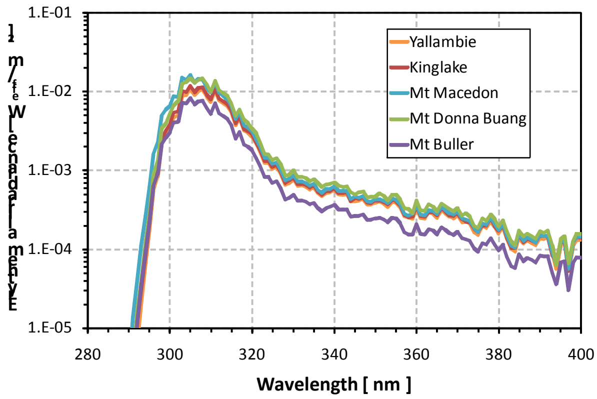

Figure 2. Erythemally weighted spectral irradiances for solar zenith angle 25° measured at five altitudes.

22% / km for UVR, 19% / km for UVA, and 30% / km for UVB.

Conclusions

Clear evidence of the altitude effect was observed in this measurement campaign, although some of this difference was likely due to the influence of urban pollution. Further measurements are being planned to test this proposition. Linear fits to the data obtained for SZA 25° give an altitude effect of 22% / km for UVR, 19% / km for UVA and 30% / km for UVB. These observations appear to be towards the upper end of the range reported in the literature.

Acknowledgments

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Effect of snow albedo and topography on UV radiation

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Abstract. Erythemally weighted irradiance measurements from four Alpine sites were analysed with respect to surface albedo. During winter, UV irradiances at pristine alpine sites with extensive snow coverage can be on average 60% higher than lower-altitude sites. These UV enhancements are due to higher effective surface albedo and lower aerosol content. Significant tropospheric ozone absorption might also influence UV measurements at the urban site. Enhanced UV radiation from snow covered mountain slopes was inferred for the specific situation at Davos.

Introduction

Quality assured measurements of erythemal weighted solar UV irradiance from four Alpine sites in Austria and Switzerland were analysed for the period 2007 to 2009. The measurements were obtained with broadband filter radiometers and archived as 10 minute averages. The four sites are located at different heights above sea level and are within 80 km of each other. Table 1 summarises the main features of each site.

Table 1. Site information and peak UV and daily doses over the period 2007 to 2009. Doses are given in standard erythemal doses (SED), where 1 SED=100 Jm^{-2} erythemally weighted UV.

Site	Lat	Long	Altitude /m	Max UVI	Dose /SED
Innsbruck (AT)	47.26 N	11.38 E	577	8.1	52
Davos (CH)	46.80 N	9.83 E	1610	10.4	57
Hafelekar (AT)	47.31 N	11.39 E	2275	9.7	59
Weissfluhjoch (ch)	46.83 N	9.82 E	2540	10.8	60

Hafelekar is situated on the mountain top just above Innsbruck with a horizontal distance to the ground site in Innsbruck of less than 3 km. Similarly, Weissfluhjoch is located in a skiing area directly above Davos, with a horizontal distance to Davos of less than 2 km. Innsbruck is considered an urban environment with non-negligible anthropogenic pollution from heating and car exhausts.

Relative differences from Innsbruck

The measurements from all sites were initially cloud-screened to obtain common cloud-free periods at all four sites. The remaining 85 days were analysed using morning measurements at 70 solar zenith angle (SZA) so that systematic effects due to changing solar elevations would not affect the interpretation of the results. The SZA was chosen because at the latitudes under study 70° is the lowest common solar elevation found during the whole year. Figure 1 shows the relative differences of each site to the lowest site Innsbruck for the cloud-free selections.

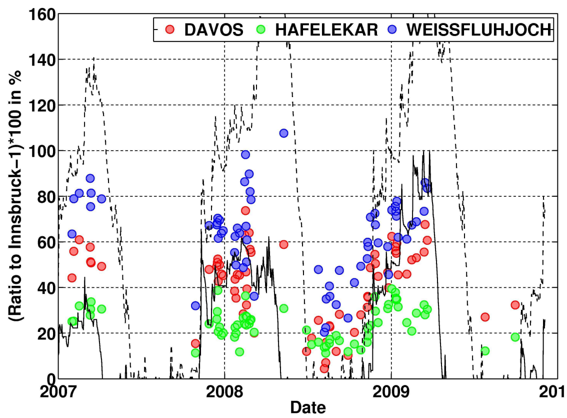

Figure 1. Relative differences in % of cloud-free erythemally weighted irradiances at 70 SZA relative to Innsbruck. The thick and dashed lines represent the snow height in cm at Davos and Weissfluhjoch respectively[1].

As can be seen in Figure 1, the relative differences between Innsbruck and the higher altitude sites are much larger in winter than in summer, reaching UV enhancements of 80 to 100% at Weissfluhjoch. Table 2 contains the average relative differences for the winter (December to February) and summer (June to August) periods.

Table 2 Average relative differences (%) of erythemally weighted irradiances at 70 SZA relative to Innsbruck, 577 m a.s.l. Winter is defined as from 1 December to 1 March and summer from 1 June to 31 August.

Site	Height difference /m	Summer	Winter
Davos	950	17%	46%
Hafelekar	1698	17%	28%
Weissfluhjoch	1963	36%	64%

As can be seen in Table 2, the altitude differences between the sites are not able to explain the large UV variations since the UV radiation in Davos, 1610 m a.s.l., is equal to or higher than at Hafelekar, 2275 m a.s.l. even though the elevation of Hafelekar is much higher than Davos.

The UV enhancements observed at these locations in the European Alps can be put into the context of a case study performed between Mt Hutt and Christchurch in New Zealand; the observed UV enhancements on two days

[1] Snow-height information was kindly provided by Dr. Christoph Marty, WSL SLF.

in spring where 30% and 23% for a height difference of 2050 m which are much lower than the corresponding values found in our study.

Effective surface albedo

The effective surface albedo represents the reflectivity of a homogeneous surface which produces the same downwelling UV irradiance as in the presence of an inhomogeneous surface. The effective albedo is used in one-dimensional radiative transfer models where the lower boundary condition (surface) is homogeneous.

In this study, the radiative transfer model uvspec was applied to the UV measurements of Davos to retrieve the effective surface albedo needed to reproduce the UV measurements. In addition to the cloud-free measurements, ancillary parameters such as total column ozone from a co-located Brewer and spectral aerosol optical depth from a precision filter radiometer (PFR) were used to constrain the model calculations. Figure 2 shows the effective surface albedo values retrieved for the period 2007 to 2009 for clear sky cases.

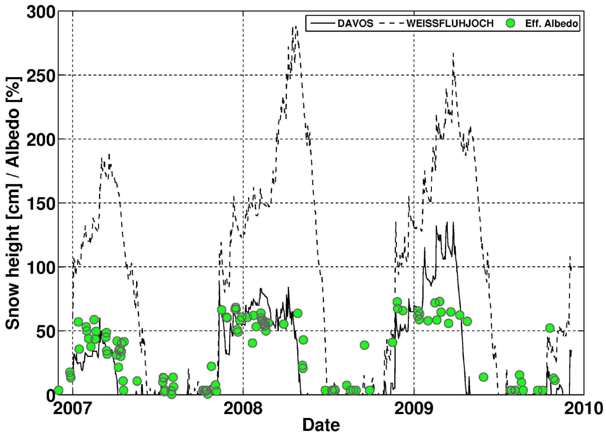

Figure 2. Effective surface albedo in % for Davos for cloud-free situations retrieved from radiative transfer calculations. Thick and dashed lines as in Figure 1.

The average surface albedo retrieved during the summer period is 0.06 with a standard deviation of 0.04, while in winter it is 0.57 with a standard deviation of 0.08. The summer values are consistent with essentially snow-free surroundings, while the winter values are very high due to the complete snow cover at Davos and the surrounding area which is for the most part above the tree line. As can be seen in Figure 2, the effective surface albedo in Davos follows closely the snow height measured at Davos, dropping rapidly to summer values once the snow melts. Similar calculations were performed on a few selected days at Innsbruck assuming total column ozone values from a nearby station and aerosol characteristics of an urban city (measured AOD and assumed SSA of 0.9). Even though assuming a very low effective surface albedo of 0.1 in winter and 0.03 in summer, model calculations systematically overestimate the measurements by 7% and 5% in summer and winter respectively. The measurements and model calculations could be reconciled if the single scatter albedo is set to unrealistic low values. More likely would be the presence of about 10 to 15 DU of local tropospheric ozone which would reduce the modelled irradiances by about 3 to 5%.

Effect of topography

The influence of snow covered mountain slopes on UV irradiances measured in a valley was investigated at Davos by comparing the enhancement of UV radiation observed in winter with respect to the summer. At Davos, this enhancement due to snow covered surfaces is 29% at a fixed SZA of 70, while it is 25% at Weissfluhjoch which is situated above Davos close to the mountain top.

The local horizon at Davos obstructs 5.4% diffuse irradiance (assuming an isotropic diffuse UV radiation distribution), while at Weissfluhjoch this obstruction is negligible. The reflected UV radiation from the snow covered mountain slopes can be estimated to 4% by assuming a local snow reflectivity of 0.9, and a diffuse to global UV irradiance ratio of 0.85, which is in good agreement with the winter to summer UV enhancements seen between Davos and Weissfluhjoch.

Seasonal peak UV

Peak UV and daily doses were determined for the spring months at the European sites and compared to two New Zealand sites. While Innsbruck is lower or equal to Christchurch, all other mountain sites show substantially higher UV values due to the enhancements from the snow cover.

Table 3 Peak UV dose rates for February (August), March (September) and April (October) at four European and two New Zealand sites. Measurements from Mt Hutt are from 13 September and 23 October 2003 only.

Site	Max UV-I			Dose /SED		
	Feb	Mar	Apr	Feb	Mar	Apr
Innsbruck	2.1	3.2	5.4	13	21	35
Davos	3.8	5.6	7.7	18	28	45
Hafelekar	2.8	4.4	6.2	16	28	44
Weissfluhj.	4.0	6.2	8.4	21	33	51
Christch.	2	4	6.5	11	20	35
Mt. Hutt	n/a	4.3	6.9	n/a	n/a	n/a

Conclusion

Erythemally weighted UV irradiances were found to be substantially higher in Davos and Weissfluhjoch than in Innsbruck and Hafelekar. While the much higher effective albedo in the Davos area is responsible for a major part of the observed radiation enhancement, substantial aerosol and possibly tropospheric ozone absorption is required at Innsbruck to explain the remaining differences between the sites.

In spring, monthly peak UV dose rates observed in the pristine snow covered sites of Davos and Weissfluhjoch are found to be higher than for the corresponding months at Christchurch in New Zealand.

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Environmental impacts of ozone depletion and its interactions with climate change

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Abstract. The key climate change factors that are likely to have the biggest impact on terrestrial ecosystems include increasing greenhouse gas emissions, rising temperatures, frequent drought and flooding events. Superimposed on these are increasing levels of UV-B (280–315 nm) radiation due to stratospheric ozone depletion as well as changes in cloud cover, pollution levels, deforestation, and subsequent land-use change, all of which are likely to increase UV-B radiation reaching biological systems. This situation makes it important that research continues to focus on potential interactions among the different environmental conditions.

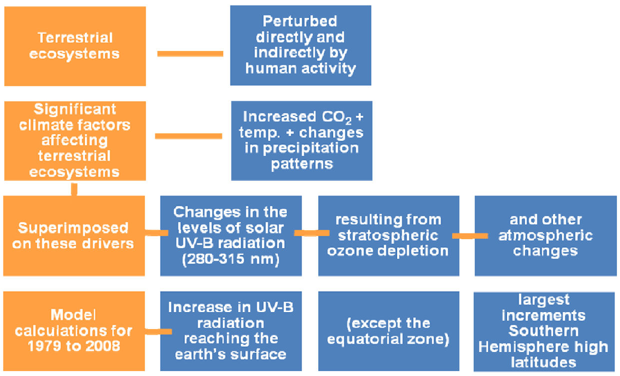

Figure 1. Complex environmental changes likely to have significant impacts on terrestrial ecosystems.

Current assessment and predictions of implications of increasing UV-B radiation and other environmental changes

The success of the Montreal Protocol has removed the large impact of the ozone depleting substances. However, it is becoming clear that the predicted elevated UV-B

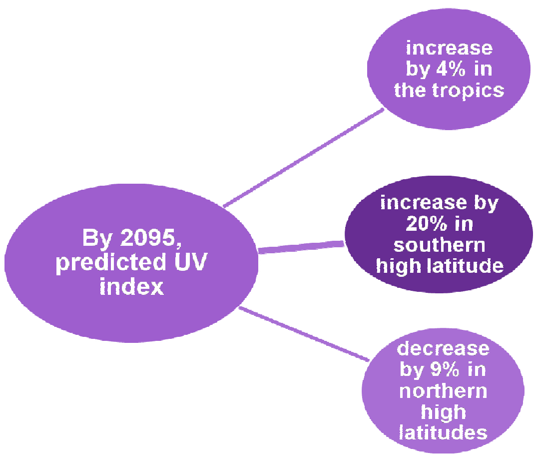

Figure 2. UV irradiance will not necessarily follow ozone recovery, but will be modified by other climate-induced changes (data from Hegglin & Shepherd 2009).

The consequences of climate change interactions include spreading of vector-borne diseases into new geographical locations, changes in species competitiveness and vitality, as well as a range of indirect effects. Modern agricultural practices are primed to further unbalance life on Earth unless concerted action is taken. Overlaid on the direct impact of changes are the many feedback processes of, for example, increased UV radiation, CO_2 and other greenhouse gases, aerosol concentrations and the biogeochemical cycling of compounds including carbon, nitrogen, methane and bioavailable toxic substances.

The main ecological consequences of an increased UV-B radiation component for several plant systems are decreases in biomass production, and changes in species composition and abundance. Depending on the environmental factor, plant response to UV-B radiation can convey tolerance to other environmental conditions, and may result in a greater or lesser tolerance. One such example is the often reported decrease in herbivory that appears to be due not only to some direct effects on insects, but also to the UV-induced increases in phenolic compounds by the host plant (Caputo et al. 2006, Izaguirre et al. 2007).

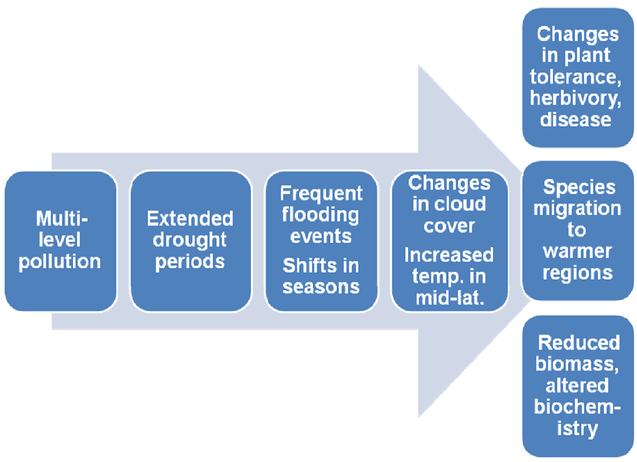

Figure 3. Complexities of climate change and their impacts.

Other interacting environmental factors which have been shown to increase tolerance to UV-B radiation in some plants are drought, freezing temperatures and warming (Feng et al. 2007, Turnbull et al. 2009, Cechin et al. 2008, Teklemariam & Blake 2004). Several lines of evidence point to a reduction in reactive oxygen species as one acclimative response (Han et al. 2009).

Although there is not much penetration of solar radiation of the UV component into soils, biomass and morphology of root systems can be affected much more than the above-ground plant shoots. These systemic responses of plants to UV-B radiation can affect also the below-ground environment for other organisms. One of a growing number of examples is the UV-B-induced increase in phenolic compounds in leaves which can also result in an increase in these compounds in plant roots, resulting in a reduction in roundworms below ground surface (Koti et al. 2007).

Conclusions

The complexity of the impacts and feedback processes of climate change are altering terrestrial ecosystem response and functioning, and are likely to intensify as climate change is enhanced. The interactive effects of UV-B radiation with other climatic variables can result in no discernible response or changes in resilience. These biological responses are likely to contribute to an evolving set of acclimation and adaptation strategies or impaired functioning, making the study of UV-B radiation effects within the framework of a changing climate of importance for understanding current and future climate impacts on terrestrial ecosystems.

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Proxy methods to estimate UV

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Abstract. Depletion of stratospheric ozone since the mid 1970s has led to significant increases in Ultraviolet B (UV-B) irradiation over Antarctica. Plants produce photo-protective flavonoids that act as sunscreens to reduce cellular damage. These compounds are stable once dried and may be used as a proxy method to reveal historical levels of UVB radiation. The flavonoid contents of herbarium samples of the moss *Bryum argenteum* collected in Antarctica before and after the formation of the ozone hole were compared. Regression analysis showed the ratio of di-hydroxylated to mono-hydroxylated flavones increased significantly with increasing modelled midday UV-B/PAR ratio ($p<0.001$), and decreasing ozone concentration ($p<0.001$). We emphasise the utility of this ratio in interpreting historical ozone trends rather than relying on changes in total flavone concentrations alone. Factors such as cloud cover can have a significant influence on UV-B dose at ground level, modifying the flavonoid content of the specimen and adding considerable variability to the results.

Introduction

UV-B radiation damages a variety of biologically significant molecules, including nucleic acids, proteins and lipids. Secondary plant metabolites are often implicated in the protection of plants from damaging UV-B radiation (Caldwell et al. 2007), and their up-regulation is a most common response to UV-B stress in land plants (Ryan et al. 1998). Flavonoids absorb strongly in the UV-B spectrum and harmlessly dissipate the absorbed energy, preventing photochemical damage. They are also effective free radicals scavengers.

Di-hydroxylated flavonoids, which have an extra hydroxyl group attached to the core of the flavonoid molecule, are preferentially up-regulated by UV-B radiation compared to their mono-hydroxylated counterparts. Their absorption spectra are similar, and the extra OH may confer improved antioxidant scavenging (Smith & Markham 1996).

We used High Performance Liquid Chromatography (HPLC) to compare flavonoid concentrations in herbarium specimens of the moss *Bryum argenteum* collected from the Ross Sea region before and after the formation of the ozone hole in the mid 1970s. In particular, we examine whether ozone-induced increases in ambient UV-B radiation have caused an increase in the ratio of di-hydroxylated to mono-hydroxylated flavones in preserved specimens of Antarctic mosses.

Results and discussion

Flavonoids may be particularly useful indicators of environmental change as they are rapidly produced in higher plants in response to stressors such as UV-B, and are unusually stable over very long periods of time (Markham 1982).

Our initial findings, using moss specimens from the Ross Sea region, show that total flavonoid concentrations increased significantly after the development of the annual ozone hole ($P<0.001$, data not shown, see Ryan et al. 2009). Results from the two years with the most data are shown in Figure 1. Di and mono-hydroxylated flavones were present in approximately equal concentrations in the pre-ozone hole samples of 1965, but in 2004 the ratio increased to approximately 2:1.

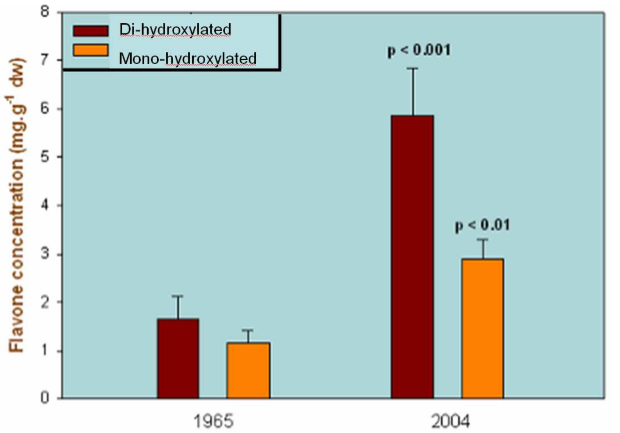

Figure 1. Mean di- and mono-hydroxylated flavone concentrations from 1965 and 2004. Error bars are standard error of the mean.

Lower pigment compositions in our extracts of older herbarium specimens may have been due simply to degradation with time. However, flavonoids are perhaps the most stable plant metabolites, and have been useful in a number of long-term studies (Björn & McKenzie 2007). Nevertheless, if samples are not stored correctly, there is still potential for degradation.

Elevated levels of UV-B result in up-regulation of di-hydroxylated flavonols (Ryan et al. 1998). We propose that since there is no reason that di- and mono-hydroxylated flavonoids should degrade at different rates, a comparison of the ratios of the concentrations of the two should eliminate any effect of pigment loss. Even if some degradation has occurred during herbarium storage, we argue that the ratio will still reflect the native state at collection and thus provide an important new method for the analysis of historical ozone trends.

Ozone data were obtained from Halley Station (75° S) (J. Shanklin, pers. comm.) and the mean daily ozone concentration for the two weeks before collection was calculated for each sample. A regression analysis shows a highly significant negative relationship between di:mono ratio and mean daily ozone (Figure 2, $P<0.001$). Considerable variability in the data is clearly evident.

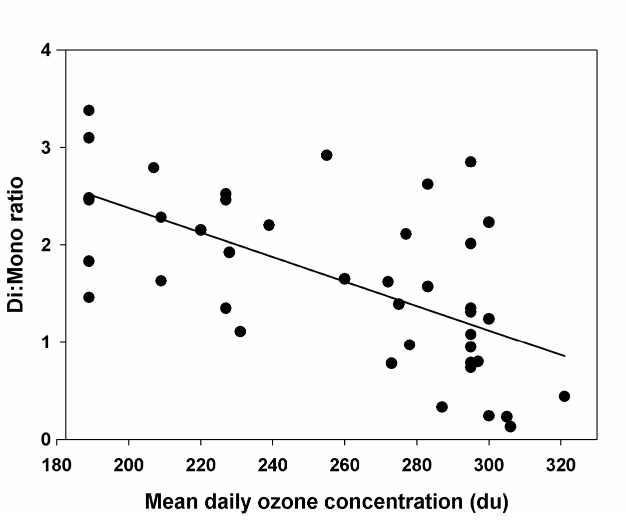

Figure 2. Linear regression between di:mono ratio and mean ozone level for 2 weeks before sample collection. $R^2 = 0.39$.

An attempt was made to eliminate this variability further by comparing the di:mono ratio with UV-B radiation estimated for each site. While some measurements of UV-B radiation are available for the Ross Sea region from Arrival Heights (Lat. 78° S), this dataset begins in 1990. Modelled clear sky UV-B and photosynthetically active radiation (PAR) data for the period covered by these samples were obtained using the interactive online radiative transfer model, TUV (Madronich & Flocke 1997). The model includes a latitude parameter and we argue that this should reduce variability further. While the relationship between L:A ratio and UV-B/PAR was also highly significant (Figure 3, $P<0.001$), the R2 value (0.28) was lower than that for the ozone comparison indicating more variability. The reasons for this are not understood.

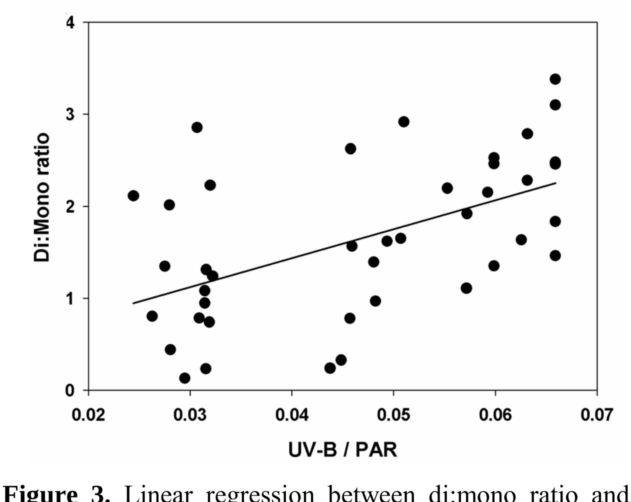

Figure 3. Linear regression between di:mono ratio and UV-B/PAR. $R^2 = 0.28$.

Although the relationship between ozone and L:A ratio in our data was highly statistically significant, more than 60% of the variation is still unexplained. In many of our samples, low ratios may have been due to local environmental factors, rather than changes in ozone. Unfortunately, apart from the 2004 samples we collected, we do not know the local weather conditions in the two weeks before the collection of the herbarium samples.

Even though tropospheric UV-B levels may be high due to depleted stratospheric ozone, clouds or snow cover can attenuate the UV-B radiation received at ground level. Furthermore, while depletion of Antarctic stratospheric ozone occurs in spring, near normal levels are recorded later in summer. Thus, flavonoid levels from more recent herbarium samples collected in late summer may reflect non-ozone hole conditions. Thus, while herbarium samples may offer tantalising possibilities in revealing historical ozone levels, it must be accepted that there will be unavoidable variability among the samples that reflect the combined influences of cloud cover, snow cover, season, temperature and shade at the time of collection. While up-regulation of phenylpropanoid metabolism may be primarily induced by exposure to UV-B, these other factors will modify rates of flavonoid accumulation and add scatter to the data. In spite of these confounding factors, the influence of changes in ambient UV-B radiation due to differences in overhead ozone concentration is still apparent in our data. The variability may be reduced by employing ratios of di:mono-hydroxylated flavonoids rather than using changes in total concentration, and this ratio provides a good proxy for recording past changes in stratospheric ozone concentration.

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UV radiation in New Zealand: implications for grape quality

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Abstract. Here we report preliminary findings from current research on the effects of ultraviolet (UV) radiation on grape chemistry under New Zealand field conditions. Treatments were applied by shielding the fruit zone of sauvignon blanc vines from solar UV radiation with plastic filters that had differential transmission spectra. We hypothesised that the differential application of UV treatments will affect grape quality. High performance liquid chromatography was used to examine UV effects on grape quality characteristics. The results showed a number of UV-induced effects in grape berries. While grape morphology was affected mainly by UV-B, levels of UV-absorbing compounds in grape skins increased with decreasing UV wavelengths. This has implications for vineyard management and wine quality.

Introduction

Compared to similar temperate latitudes in the northern hemisphere, levels of UV radiation in New Zealand are relatively high. This is due to several natural and anthropogenic factors and affects the UV-A (315–400 nm) and particularly the UV-B (290–315 nm) region of the solar spectrum (Seckmeyer et al. 2008). While UV-B, and to a lesser degree UV-A, have been described as stress factors for plants, these wavelengths can also fulfil important regulatory roles in plant function (Ulm & Nagy 2005).

Due to their sessile nature, plants cannot avoid UV radiation and therefore have evolved a number of adaptive mechanisms to protect themselves against negative stress effects. Examples of such adaptations include thicker epidermal cell layers and accumulation of sunscreens to absorb UV (Hofmann et al. 2000). The flavonoids are a key group of UV-absorbing plant pigments. These compounds are frequently found in epidermal cell layers at the plant surface and are also known to act as antioxidants that can affect important wine quality characteristics (El Gharras 2009, Rice Evans et al. 1997).

Little is known about the effects of UV radiation on grape vine cultivars growing in New Zealand, and on the resulting grape juice and wines. The aim of this study was therefore to examine responses to UV radiation in New Zealand-grown grapes.

Experimental

Plants of the grapevine (*Vitis vinifera* L.) cultivar sauvignon blanc were investigated during the 2007–08 growing season in a research vineyard at Lincoln University, Canterbury, New Zealand (Figure 1).

Figure 1. UV experimentation in the research vineyard at Lincoln University, Canterbury.

Using plastic filters with differential transmission of UV radiation, the fruit zone of sauvignon blanc vines was exposed to three solar UV treatments: (i) to all UV wavelengths, providing near-ambient UV levels ('UV-A & UV-B'), or (ii) only to UV-A ('UV-A'), or (iii) it was shielded from most solar UV ('Lo UV') (Figure 2).

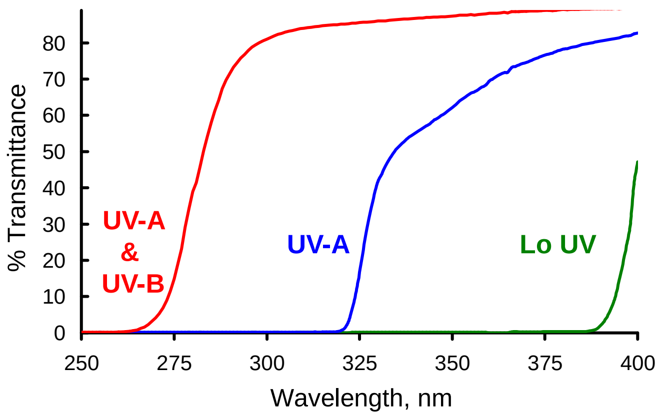

Figure 2. UV transmittance of the filters used in the study.

A special emphasis was placed on grape berry biochemistry. High performance liquid chromatography (HPLC) was used to examine UV effects on the accumulation of total UV-absorbing compounds, including flavonoids in methanolic grape skin extracts (Hofmann et al. 2000). Grape juice was also analysed for sugar and amino acid levels and the berries were examined pre-harvest for signs of morphological damage.

Results and discussion

The morphological observations in grapes revealed wavelength-dependent effects of ambient New Zealand UV radiation. Grape skin damage, in the form of 'brown sunburn spotting', was not present in plants grown under filters that only transmitted UV-A or no UV radiation (Figure 3A), but became apparent when plants received UV-B (Figure 3B). This specificity within the UV spectrum for symptoms of morphological damage underlines the role of UV-B as *the* sunburning waveband for grapes and other horticultural crops (Schrader et al. 2003).

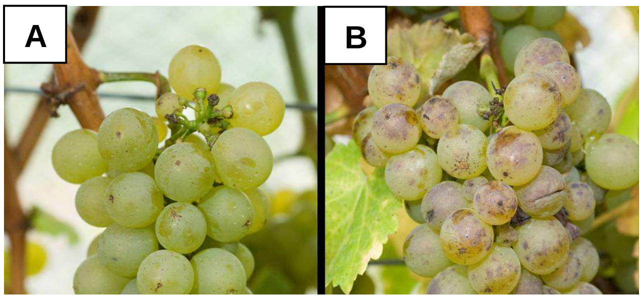

Figure 3. Grape berries grown under filters that exclude (A) and transmit UV-B (B).

The accumulation of protective UV-absorbing compounds, including flavonoids in grape skins, increased with decreasing UV wavelengths. Compared to the 'Lo UV' treatment, the accumulation of UV-absorbing pigmentation was double in grape skins grown under UV-A-transmitting filters and triple when grape berries were exposed to the full solar UV spectrum (Figure 4). UV-absorbing compounds such as flavonoids have high absorbance in the UV-A and UV-B region of the solar spectrum and also can serve as antioxidants that scavenge free radicals induced by UV-B (Rice Evans et al., 1997).

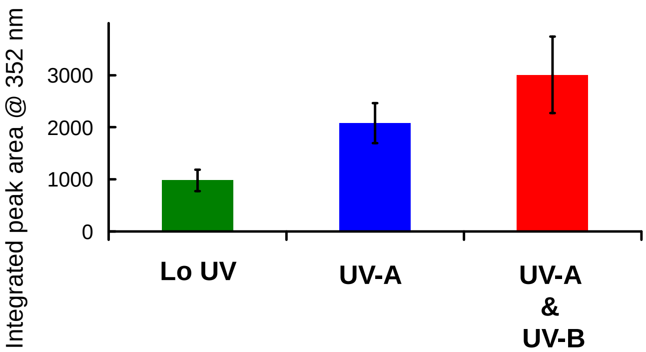

Figure 4. Total HPLC peak areas of UV-absorbing compounds in skin extracts from grape berries grown under three UV filter treatments. Error bars are ± SE.

Preliminary results also indicate that sugar levels are increased by UV-B radiation. Further experiments are in progress to confirm this finding.

Conclusions

These studies show UV-induced effects on important grape quality parameters. UV-induced increases in UV-absorbance and antioxidant potential of the grape tissue will also affect quality characteristics in grape juice and wine and this will become a focus for future studies. The knowledge of specific UV effects on grape berry quality needs to be taken into account in the management of grapevine canopies, e.g. in regard to timing and intensity of vine leaf removal during the grape berry ripening process.

Acknowledgments

We thank Jackie White for technical assistance. Funding for this work is acknowledged from Lincoln University and Trinity University.

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Improved UVI products at NIWA

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Abstract. At the last UV workshop four years ago Turner et. al. (2006) listed several improvements to NIWA's publically available UVI forecasts they thought possible by 2010. Here, I review what improvements have been made and what improvements are in the pipeline for later this year. Generally, the delivery system has been made more robust by standardising coding procedures and shifting to netcdf CF compliant input files all with the intention of moving the production of UVI forecasts to within an "ecoconnect" framework by September 2010.

NIWA's UV Index forecasting

NIWA has provided UV index (WMO 1994) information to the New Zealand public online at its website (www.niwa.co.nz/our-services/online-services/uv-and-ozone) and by distribution to the media via MetService™ (Marks & McKenzie 1997, McKenzie & Renwick 2002) for over a decade now. A cloudy sky UVI product was introduced in 2005 (Turner et al. 2006) using cloud fields from a fairly coarse mesoscale weather model (RAMS with ΔX=20 km). However, the failure to capture small-scale cloud features combined with the fact that the RAMS forecasts took a long time to complete (forecasts were 1 day old before being ready) meant that the cloudy sky UVI product has not been heavily promoted.

These drawbacks were recognised after a trial period in the summer of 2005–06. At the last UV workshop Turner et al (2006) listed several improvements to NIWA's publically available UVI forecasts they thought possible by 2010. These included a switch to using NZLAM for the cloud fields and the provision of movie loops showing the forecast hour-to-hour variation in ozone, clear sky UVI, and cloudy sky UVI (see Figure 1 for a snapshot of the frames in such a loop). Note NZLAM (pronounced "NZ Lamb") is a New Zealand configuration of the United Kingdom's MetOffice weather model (called the Unified Model (UM)) and was described by Webster et al. 2008.

In this presentation I review which of the improvements have been made so far and what improvements are definitely to be completed by later this year.

Improvements made so far

The transition to using NZLAM cloud fields has taken longer than anticipated. This has been for a number of reasons, but the main one has been the requirement to develop/upgrade and deploy the system within NIWA's ecoconnect framework.

Ecoconnect requires (i) code that conforms to ECMWF programming standards and (ii) input datasets and output files to be in a netcdf CF compliant format. These are non-trivial demands to comply with and have introduced a high transition cost; however, the advantages are a more robust, versatile, and greatly improved delivery system, within which any future upgrades will be easier to implement. The necessary coding changes to comply with ecoconnect demands have now been completed.

Another improvement made has been an updating of the "UV lookup" tables used in calculating the clear sky surface erythemal UV. These still have same six parameters; overhead ozone column, aerosol optical depth (1000 nm) atmospheric pressure, solar zenith angle, albedo, and altitude, but have more reference points so the interpolations to the erythemal UV are more accurate.

Another improvement has been to produce a "city-max" product – which as the name sounds is just the peak value of UV Index for a particular location and day.

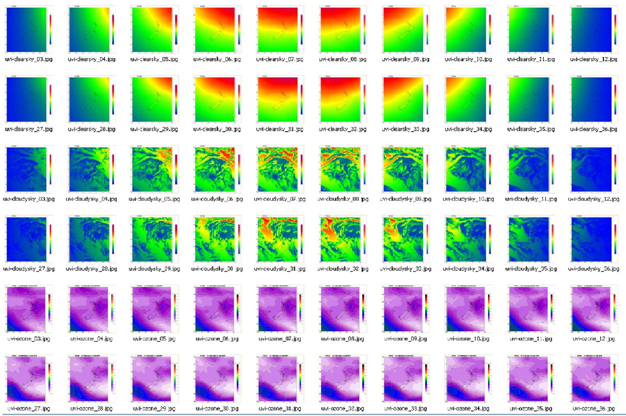

Figure 1. Forecast hourly thumbnails for daylight hours for 31 March and 1 April 1 2010 of UV Index clear sky (top 2 rows) UV Index cloudy (middle 2 rows) and ozone (bottom two rows)

Improvements due by September 2010

Hourly snapshots of cloudy sky UVI (as well as clear sky UVI and ozone field) are due to be available within ecoconnect by September 2010. In terms of cloud effects, we do expect better results from the NZLAM as the forecasts are (i) available approximately 18 hours earlier than from RAMS, (ii) the model warm starts, i.e., it does not need to "spin-up", (iii) it assimilates satellite data, and (iv) numerical errors introduced at the lateral boundaries take longer to reach New Zealand as the domain is much larger (Figure 2) than RAMS. Visual examination of both RAMS and NZLAM cloud fields for a number of cases support this view. In 2011 the NZLAM cloudy UVI forecasts for the 2010–11 summer will be verified.

The NZLAM cloud forecasts are available twice daily at about, initially, 0600 and 1800 UTC on a grid with ΔX=12 km (soon to be ΔX=1.5 km), but it is planned that UV forecasts will still be done only once a day in the early afternoon. The move to a 1.5 km grid is exciting as this should provide much more of the small scale detail that is missing from the current RAMS (and for the NZLAM-12 see Figure 2) cloudy sky UVI forecasts. Note, both RAMS and NZLAM use "band radiation models" with NZLAM using a generalised 2 stream Slingo-Edwards radiation model (Edwards et al. 2004); the cloud effects on UVI are estimated by comparing the radiation in the SW bands at the ground versus the radiation in the SW bands at the TOA.

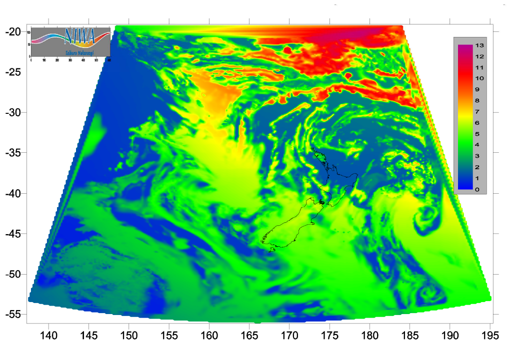

Figure 2. Cloudy sky UV Index at 0000 UTC 24 October 2009 for entire NZLAM-12 domain.

The look and features of ecoconnect

While ecoconnect has the look and feel of one it is not a website, but an application which is distributed to a user's machine. The user goes to the NIWA website and launches ecoconnect from there and gains access with a username and password. Given the data transfers involved, high speed internet access is essential.

Figure 3 shows a time series of forecast and observed (when available and up to the current time) temperature, humidity and wind for a specific location (Queenstown in this instance) as it appears within ecoconnect. A list of the many locations available is displayed on the left; actual values can be shown by moving the cursor over the trace.

Contour plots – with a possible choice of 5 domains: "All New Zealand", "Southern NZ", "Central NZ", "Northern NZ", and "East Australia to past the dateline" (see Figure 2) – will look as shown in Figure 4. Hourly movie loops of UVI clear sky, UVI cloudy, and ozone will be available.

Beyond 2010

Looking forward another four years, once the transition to ecoconnect and 1.5 km configuration of NZLAM is completed, then a possible item to address would be the mismatch in scales between the ozone (~100 km) and cloud (1.5 km) input fields. Maybe we will be including ozone data assimilation and forecasts by 2014.

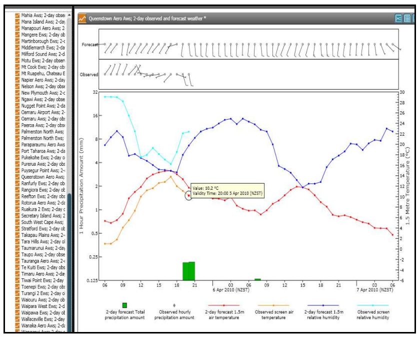

Figure 3. Sample ecoconnect display of time-series of forecast and observed (up to current time) of various environmental variables.

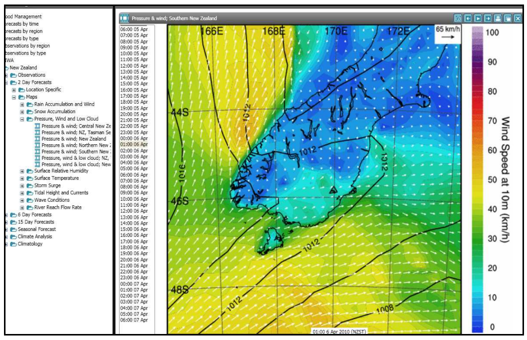

Figure 4. Sample ecoconnect display of contour maps of wind speed and isobars. Similar looking UV Index clear sky and cloudy plus ozone fields will be available within ecoconnect from September 2010.

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UV dosimeter based on polyphenylene oxide for the measurement of UV exposures to plants and humans over extended periods

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Abstract

Long-term solar UV measurements made by Poly (2, 6-dimethyl-1, 4-phenylene oxide) (PPO) dosimeters with a polyethylene neutral density filter (NDF) are presented. These measurements show that the life span of a PPO dosimeter can be effectively doubled before saturation. Therefore, as the dynamic range of PPO film is known to be approximately seven days during summer at a sub-tropical location, the advantage of using a NDF is that half the number of dosimeters will be required to be prepared and analysed before and after solar exposure. In addition, we show how the spectral response of the PPO dosimeter closely resembles the erythemal response and how the PPO dose response varies in accordance to changes of the solar spectrum resulting from seasonal changes and atmospheric ozone.

Introduction

Thin films based on Poly (2, 6-dimethyl-1, 4-phenylene oxide) (PPO) have been developed for use as UV dosimeters (Berre & Lala 1989). More recent research has characterised the properties of PPO for use as a UV dosimeter to measure long-term erythemal and UVB exposures to humans, in aquatic environments and to plants (Schouten et al. 2007, 2008, 2009, 2010, Parisi et al. 2010, Lester et al. 2003). The advantage of using PPO as a dosimetric material is that its dynamic range is approximately seven times longer than that of polysulphone. This allows for the measurement of long-term exposures without the daily need to change the dosimeters in the field. Furthermore, this extended dynamic range can be doubled through the use of a neutral density filter (NDF) (Schouten et al. 2010). This paper will report on the spectral response of PPO, the variation in the unfiltered PPO calibration, and the extension of the PPO dynamic range with the use of a NDF.

Spectral response

The thin PPO film was produced at a thickness of 40 μm at the University of Southern Queensland, cut into pieces and mounted onto 3.0 x 3.0 cm thin PVC holders, each with a 1.6 x 1.2 cm central aperture to produce dosimeters. The UV induced change in the property of the PPO film to allow use as a UV dosimeter is the change in optical absorbance which is measured at 320 nm in a spectrophotometer (model UV1601, Shimadzu Co., Kyoto, Japan).

The spectral response in Figure 1 was determined by employing a 1600 W irradiation monochromator (model 66870, Oriel Instruments, USA) to expose the dosimeters with a series of measured monochromatic wavelengths with measurement of the change in absorbance of the material.

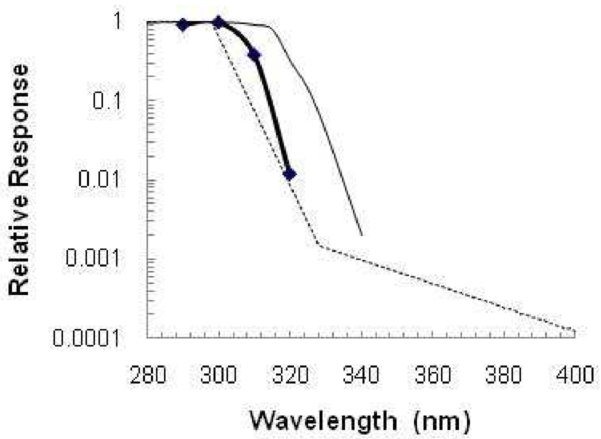

Figure 1. Spectral response of 40 μm PPO dosimeter film (thick line) compared to the erythemal action spectrum (CIE 1987) (dashed line) and the polysulphone spectral response (CIE 1992) (thin line).

Unfiltered calibration and dose response

Unfiltered calibrations of the PPO dosimeters were performed at the subtropical site of the University of Southern Queensland campus in Toowoomba, Australia (27.5° S, 151.9° E, 693 m altitude) from March 2007 to February 2008. The cumulative erythemal exposures were measured with an erythemal UV meter (model 501, Solar Light Co. PA, USA) calibrated to a spectroradiometer system (Bentham Instruments, Reading, UK) with calibration traceable to the National Physical Laboratory (NPL).

Figure 2 displays seasonal PPO calibration regimes and also compares the dynamic range of the PPO dosimeter to that of a polysulphone dosimeter calibrated in summer. It can clearly be seen that the response of the PPO dosimeter varies substantially from season to season. To eliminate the introduction of any critical errors in field solar exposure measurements caused by seasonal variations in solar zenith angle (SZA), along with varying column ozone trends, calibrations are required with respect to the source spectrum that they will be measuring in order to take into account the changes in the solar spectra.

In Figure 2 it can be seen how the dynamic range of the PPO dosimeter far exceeds that of the polysulphone dosimeter before approaching saturation. A direct comparison between the summer polysulphone calibration and the summer PPO calibration shows that the PPO dosimeter offers close to seven times more solar exposure time than the polysulphone dosimeter. This equates to an extra dosage of about 164 SED (Standard Erythemal Dose).

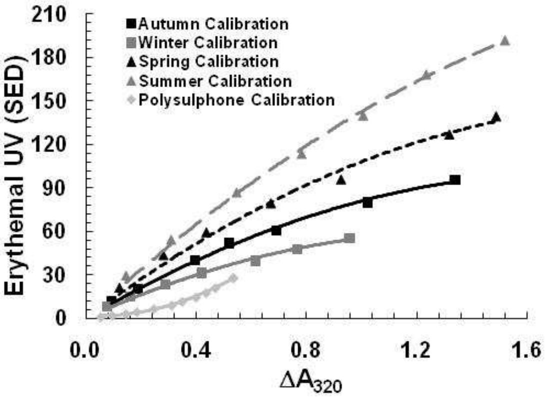

Figure 2. Calibration of PPO in each of the four seasons compared to a polysulphone calibration.

Dynamic range extension

Polyethylene was employed as the NDF material taped over the PPO dosimeter to extend the dynamic range. This material has a reasonably flat transmission in the UV waveband of interest. This attribute is desirable as it allows for equal amounts of solar energy to pass through to the dosimeter at each wavelength, which leads to the reduction of measurement uncertainty that could result from variations in the incident solar UV spectra.

The transmission spectrum of the NDF measured in the spectrophotometer is shown in Figure 3 before and after exposure to 450 SED. Although there is a drop in transmission by about 4% after exposure, this is taken into account during the calibration of the extended dynamic range dosimeters.

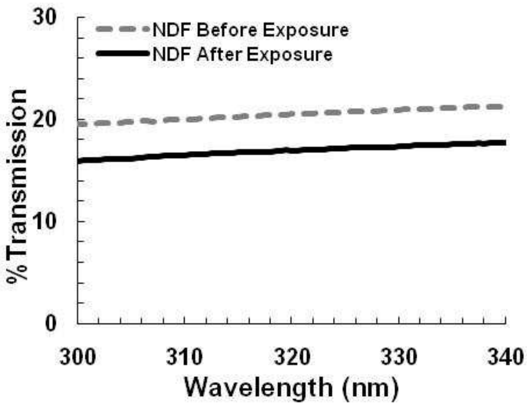

Figure 3. Transmission of the NDF before and after exposure to 450 SED.

Figure 4 displays an erythemal UV calibration obtained with the NDF attached to a batch of PPO dosimeters in autumn 2008. As with the unfiltered PPO dosimeters, this calibration was performed at the University of Southern Queensland's Toowoomba campus using the same solar UV measurement equipment. With the use of the NDF, the incoming UV wavelengths are attenuated, which changes their spectral energy distribution that in turn affects the response of the dosimeter underneath. Consequently, the PPO dosimeter must be calibrated for long-term field use with an NDF attached to it. This will also take into account any short- and long-term variations in the absorption characteristics of the NDF material.

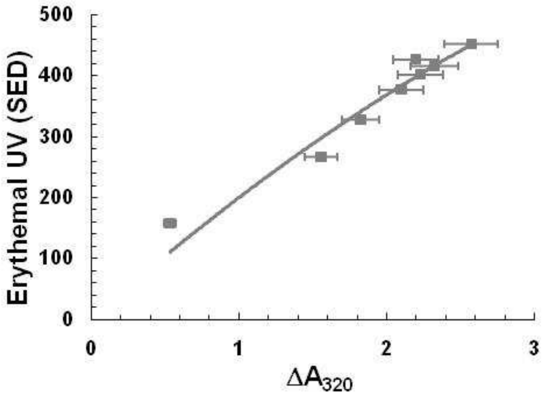

Figure 4. Calibration of PPO with the NDF.

Discussion

A UV dosimeter based on PPO thin film has been described. The dynamic range compared to polysulphone is longer by a factor of approximately seven. This allows erythemal UV measurements up to 192 SED before optical saturation. This equates to up to a week of exposure time on a horizontal plane at a subtropical site. This dynamic range is further extended with the use of an NDF to allow erythemal UV measurements up to 452 SED.

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Electronic UV dosimeters for research and education

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Abstract. Electronic dosimeter badges are replacing chemical (polysulfone) film as the optimum method of measuring personal exposure to UV radiation. Advantages include integration times of the order of seconds rather than hours/days, re-usability, and cost. A miniature wearable version, developed locally in New Zealand, has been intensively trialled at Mt Hutt ski-field to measure personal UV exposures of skiers during 2005–09. Typical UV exposures varied from 3 to 16 SED during the course of the ski-season (mid June to early October). The average UV dose received by ski instructors during a 10-day period in September 2008 was 6.3 SED, which is comparable to those received by outdoor workers during summer months in New Zealand. To date these dosimeters have principally been used in behavioural/epidemiological studies but, provided cost and ease-of-use issues are addressed, their largest impact is likely to be in school-based educational programmes, particularly in conjunction with other tools such as NIWA's web-based UV Index maps and 'on-line' UV Index instruments.

Introduction

Any instrument designed to measure personal UV exposure requires a sensor with a spectral response that matches the erythemal action spectrum (EAS) for human skin. Two ternary semiconductor systems AlGaN and ZnMgO have spectral responses in the UVB spectrum that can be tuned by varying the Al/Ga and Zn/Mg ratios respectively. Both material systems are capable of providing a close match to the EAS combined with more than four orders of magnitude of visible rejection provided crystal defects that can cause absorption in the green part of the visible spectrum are carefully controlled. Currently AlGaN photodiode sensors with an Al fraction of about 27% are used, although future ZnMgO sensors are expected to provide significant performance advantages in terms of responsivity, reliability and cost.

The electronic design of a UV dosimeter is essentially straightforward, requiring an amplifier which converts the tiny (1–10 nA) AlGaN photodiode current into a measurable voltage in the 0–2.4 V range. A micro-controller is then used to sample the output voltage at predetermined time intervals and store the results in non-volatile memory. The dosimeter is powered by a 3V lithium (CR1632) 125 mAh coin cell providing more than 3 months operating life at a sampling interval of 8 seconds. Total on-board memory capacity is 128 kbytes or 64 000 data samples (~ 12 days at 8 second sampling). The dosimeter (dimensions are 35 x 10 mm, weight 20 grams) is either pinned to clothing or used with a velcro arm- or wrist-strap. A shaped PTFE front cap acts as a UV diffuser giving an overall angular response to within 10% of a true cosine and is attached via a waterproof seal to a powder-coated brass backing plate.

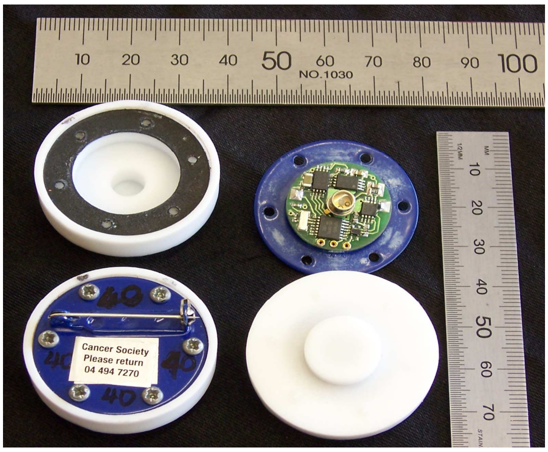

Figure 1. Electronic UV dosimeter badges + PTFE diffuser cap.

Research – Mt Hutt ski-field case study

Initial studies (Allen and McKenzie 2005, 2007) into the UV exposures at Mt Hutt ski-field (1590-2086 m, 43°30' S, 171°32' E) showed that during spring months (September & October) peak UV Index (UVI) values were ~ 30% higher than at an equivalent sea level site (Christchurch, 43°53' S, 172°61' E) with daily doses exceeding 16 SED towards the end of the season. In this updated work, UV exposure measurements were extended to cover the entire ski season which typically runs from mid June to early October each year. Measurements were carried out on predominantly cloudless days from 9:00 am to 4.00 pm, at 8 second intervals, with the dosimeter badge worn using a velcro strap on the right arm. Separate badges were also deployed on horizontal surfaces at the base and summit of the ski-field to measure the UV Index at these sites.

Figure 2. UV dosimeter badges deployed at Mt Hutt during the 2008 and 2009 ski seasons.

The calibration of the UV dosimeter badges was maintained at regular intervals against a Yankee Environmental Systems meter which is in turn maintained and calibrated against NIST standards by NIWA.

Figure 3 shows the typical UV exposure of a skier at Mt Hutt on clear sky days during each month of the ski-season. Each plot gives the erythemally-weighted UV irradiance versus time. Although the term UV index is only strictly defined for horizontal surfaces, it is used here as a convenient unit with 1 UVI = 25mWm^{-2}. Each plot was integrated to calculate the total daily dose in units of SED where 1 SED = 100 Jm^{-2} of erythermal exposure. The UV environment varies significantly over the course of the ski-season with peak irradiances and daily doses increasing dramatically during September and October.

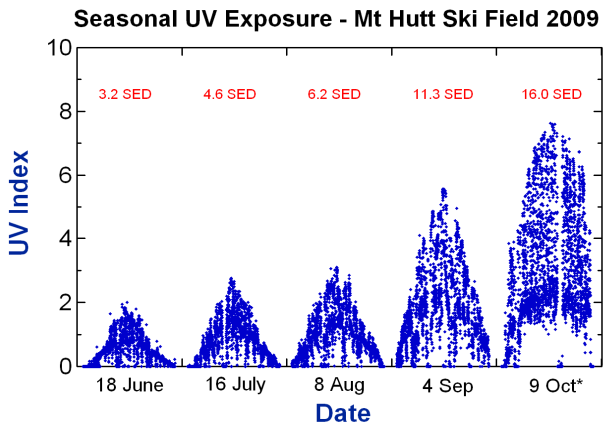

Figure 3. Typical clear-sky UV exposure for a skier at Mt Hutt during the 2009 ski season (*data taken in a previous year).

Figure 4 shows the UV exposure of a ski-instructor during a 10-day period in September 2008. The mean daily dose was 6.3 SED compared to an average of 5.3 SED measured using the same dosimeter badges during a study [*Hammond et al.* 2009] of outdoor workers from mid January to early March 2007 in Central Otago, NZ.

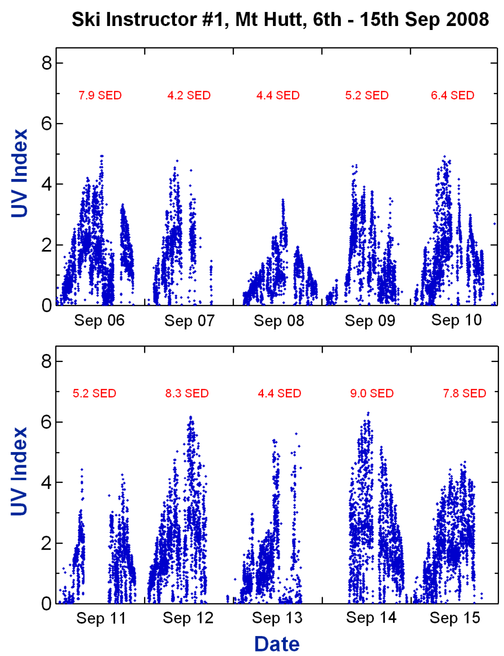

Figure 4. UV exposure for a ski instructor at Mt Hutt over the course of a 10-day period in September 2008.

Education

To date these dosimeter badges have been used in a number of behavioural/epidemiological studies.

- "UV exposure of primary school children," University of Otago/NIWA, Nov 2004–Apr 2005.
- "UV exposure of outdoor workers," University of Otago/NIWA, Jan–Mar 2007.
- HRC-GA207 - "Quantifying the association between sun exposure and vitamin D status in New Zealanders", University of Auckland/University of Otago/NIWA, 2008 – 09.

In addition to such studies, the dosimeter badges have significant potential in promoting sun-smart awareness and safe-sun practices when used in school-based educational programmes. The key assumption here is that health messages are more likely to be adopted when reinforced with hands-on activities that provide supporting evidence which students can evaluate for themselves. In other words, "finding things out for yourself is more powerful than being told what to do!" Examples of activities in which the dosimeter badges can provide quantitative data to reinforce health messages include:

- Measuring the daily UV cycle (11 am – 4 pm; high exposure period).
- Measuring the effectiveness of shade in reducing UV exposure.
- Measuring the effectiveness of different sun-screen products.
- Measuring the effectiveness of sun-glasses and different types of protective clothing.

Significantly, the UV data provided by the dosimeter badges can be used in conjunction with NIWA's web-based UV Index maps and 'on-line' UV Index instruments at selected sites across the country to provide the means for students to draw their own conclusions about the nature of UV radiation in New Zealand.

Conclusions

The utility of electronic UV dosimeter badges has been demonstrated in a number of behavioural/epidemiological studies conducted in New Zealand. Recent improvements to the ease of operation of these badges (in conjunction with D. Sherman, Scienterra Ltd.) allows their use in school-based educational programmes designed to achieve improved sun-smart behaviour through self-discovery of the issues involved.

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Personal exposures to UV radiation in New Zealand

Ben Liley[1], James Liley[2], Martin Allen[3], John Robinson[1], Richard McKenzie[1] and the UV-vitamin D team[1,2,4]

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[4]University of Auckland, New Zealand

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 Figure 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 Figure 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.

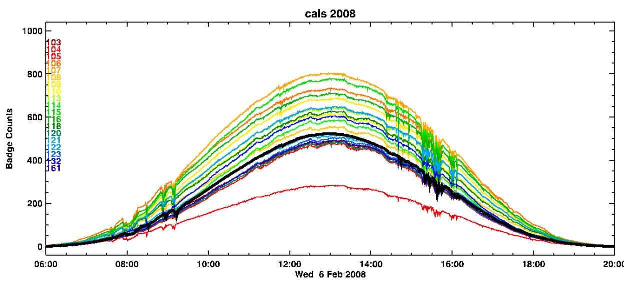

Figure 1. Calibration of dosimeter badges at Lauder on 6 February 2008, against YES UVB-1 instrument, shown as a black curve with 20 counts per UVI unit, the average over all badges.

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 Figure 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).

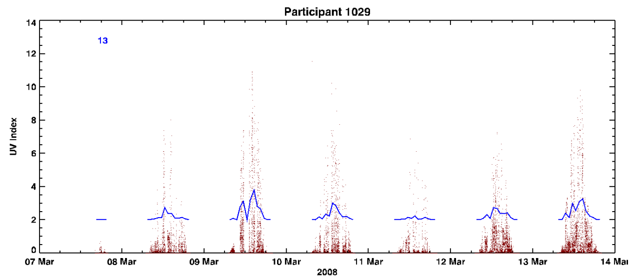

Figure 2. Example time series of daily UVI exposure for an outdoor worker in Auckland. Hourly means, shown in blue, are offset by 2 UVI for clarity.

UV-vitamin D study data

Participants wore the badges for 8 or 10 weeks, so a full data set is about 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.

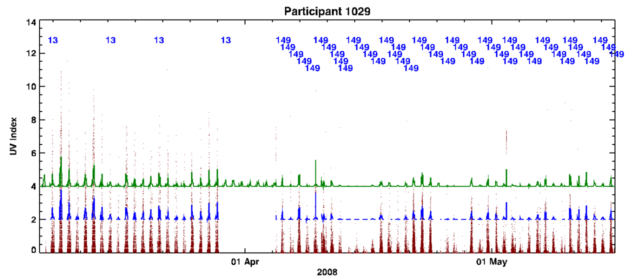

Figure 3. Initial data (dark red), hourly averages (+2 UVI, blue), and completed hourly series (+4 UVI, green).

Correction and gap filling was in two stages, described in more detail by 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 Figure 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.

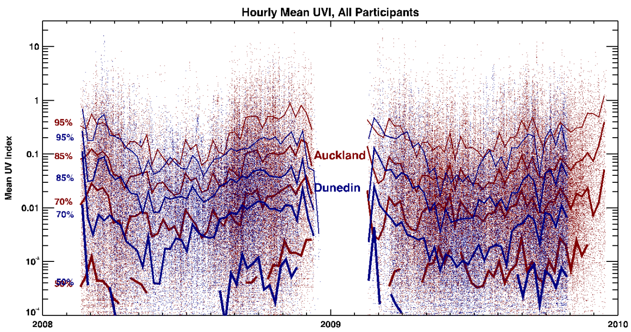

Figure 4. Hourly mean UVI for all participants in Auckland and Dunedin, with percentiles as shown.

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 Figure 5.

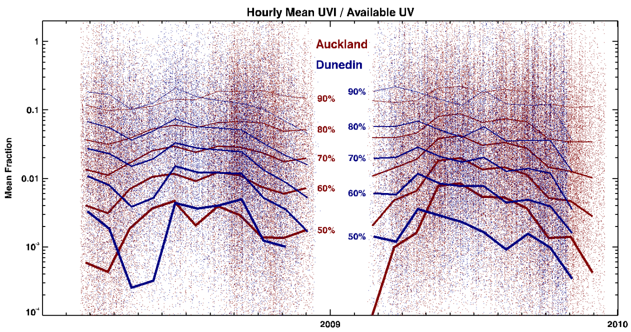

Figure 5. Hourly mean UVI for all participants in Auckland and Dunedin, as a fraction of UVI from the UV Atlas, with percentiles as shown.

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 Figure 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.

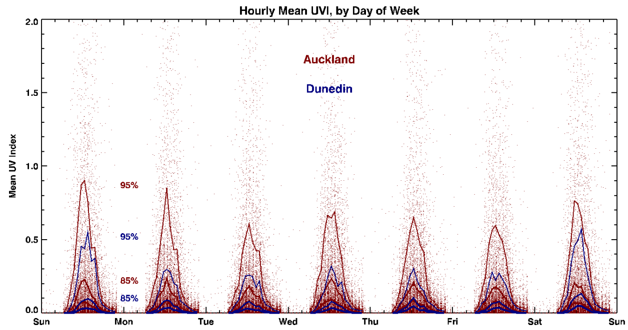

Figure 6. Hourly mean UVI for all participants in Auckland and Dunedin, over all seasons of the study, by day of the week.

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%. 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 million 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. This volume.

Personal UV dosimeter badges: Mark II

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Abstract. A new instrument has been developed for researching personal ultraviolet radiation exposure. The Personal UV Dosimeter Badge: Mark II (“Badge” for short) is designed to allow researchers and school groups to monitor the UV exposure of selected individuals. Improvements to the previous instrument include wireless connectivity, more memory, longer battery life, and a lamp to indicate that the unit is functioning.

UV dosimeter background

It has been determined that excessive UV radiation exposure is harmful to humans, but the allowable limit is difficult to quantify due to differences among individuals. To allow researchers to collect data about an individual’s personal UV exposure, a device known as a “badge” has been designed to record incident UV radiation, in a small, lightweight, waterproof, unobtrusive package that can be easily worn on a piece of clothing. This allows research subjects to gather data about their own UV exposure. By using many such badges carried by a wide cross-section of the population, an enormous mass of data can be collected.

The need for a newer dosimeter badge

The previous badge design has been highly functional, and has enabled many important studies. However, there were several shortcomings that required a redesign.

Interaction with the badges has been time consuming because of the need to disassemble each unit in order to communicate with it. Disassembly was frequently required during testing, configuration, preparation for deployment, and again for data collection. At each stage, there were multiple opportunities for screws to get lost, pins bent, or glue joints broken. Handling the bare circuit board had the potential to cause ESD damage.

Badge circuitry was mounted to the case with glue, using the back of the battery clip as a joining surface. This glue joint often released while the user was inserting the battery.

The stability of the calibration was also a concern. After disassembly and reassembly, there was nothing to ensure that the sensor sat in exactly the same place relative to the radome. The act of calibrating the sensor thus changed the sensor’s calibration.

UV-sensitive phototransistors are wonderfully inexpensive, but woefully inconsistent. Some sensors are ten times more responsive than others of the same batch. The old badge required a specific resistor to be hand-tuned to make up for this variation. Of course, each unit had to be disassembled and reassembled multiple times to accomplish this.

Once running, the old badge gave no indication that it was functional. Often, researchers would collect their badges, only to find that many of them had stopped working early in the study.

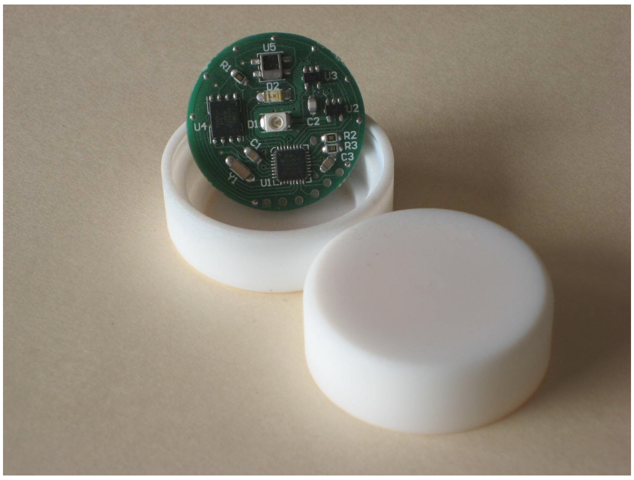

Figure 1. Personal UV dosimeter badges. Each unit is only 36 mm in diameter and 13 mm thick.

Improvements and new features

The new design corrects the problems of its predecessor, and adds a few new features of its own.

To avoid the need to disassemble each unit, new badges use wireless communication. A small integrated circuit handles incoming IR data reception, and a visible light LED serves to transmit data. Both light paths are through the radome. The visible light LED also serves as an indicator for the power-on test, and as a visible heartbeat that shows the badge is still functioning.

The UV measurement circuit has been improved. The new circuit integrates the UV signal over a short period of time, and then samples the integral. This method is inherently good at amplifying small signals, while filtering noise. It also provides an easy way to compensate for inconsistent sensor responsivity, merely by changing the integration time.

Memory was increased to 2MB. The badge stores UV data, plus battery voltage and temperature. The time intervals between measurements are set individually for each parameter. Valid intervals are between 5 seconds and 18 hours. More than a million data values can be stored before the memory is full.

The PTFE housing was modified so that the circuit board is firmly pressed into place by a water-resistant seal. No glue is used, and the battery clip can move freely.

At the time of writing, battery life has been calculated to be approximately one year, under normal conditions. A very small change to the circuit board will increase the expected battery life threefold. Note that these figures have not been tested.

A built-in clock tells the badge which hours of the day to be active. For example, a badge can be set to activate at seven in the morning, and deactivate after supper. The speed of the visible heartbeat indicates whether it is active.

Configuration and data transfer are done via a wireless cradle, which is connected to a computer via USB and a terminal emulator. Data are transmitted from the badge to the computer at approximately 40 800 baud.

Remaining issues

- Calibration and testing will be conducted this year by NIWA, Lauder. Field testing will follow.
- A new circuit board is in process for the cradle. This will improve manufacturability, and also provide other features, such as a battery backup for the time and date.
- One of the IC chips on the badge has become obsolete, and the replacement must be tested for compatibility.
- A graphical user interface (GUI) should be written. It will be easy to integrate with the USB cradle. Custom interfaces are also possible. Please contact Scienterra.

Interested?

For sales and marketing questions, please contact Martin Allen (martin.allen@canterbury.ac.nz).

Calibration of solaria

Paul V. Johnston and Richard L. McKenzie

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Abstract. Solar UV spectral measurements have been made at Lauder and other global sites since the late 1980s using spectroradiometers that have a wide dynamic range and that are calibrated to absolute traceable standards. However, these are unsuitable for absolute spectral measurements of solaria because of their size, lack of pointing flexibility and slow measurement times. For spectral measurements in the HRC UV and vitamin-D project a small Ocean Optics USB4000 miniature spectrometer has been used. The strengths and limitations of this system are outlined. Variations within solaria are shown and conclusions drawn about the overall accuracy. Solar and spectra from the solaria are shown. Using the erythemal and vitamin-D action functions, weighted irradiances are calculated for erythema and vitamin-D and compared with solar values. The "efficiency" of sunbeds compared with the sun in producing vitamin-D with minimum erythemal effects is discussed.

Background

The NIWA solar UV spectrometer system is a standard design and includes a large (300 mm focal length) double monochromator with a photomultiplier detector, precision secondary standard calibration lamp facility and accurate temperature control. They are in use in several countries, mainly in collaborative solar UV research programmes. The accompanying paper by Michael Kotkamp et al. has more information.

Miniature spectrometer for solaria use

For measurements in the confined space of solaria, we had to find a suitable compact alternative. An Ocean Optics USB4000 spectrometer was chosen.

The advantages of this spectrometer are:

- Compact, light, easy to point within sun-bed chamber
- Direct USB computer connection for power and data
- Fast spectrum acquisition (seconds)

The disadvantages are:

- Limited dynamic range (300:1)
- Expect stray light issues (single grating spectrometer)
- Relatively insensitive in UV (front illuminated CCD detector)
- Detector dark signal strongly depends on temperature (10% change in 5 min observed)

Spectrometer stray light correction

Figure 1 shows the effect of stray light in the critical 300 nm region. Note the y scale used: the spectrum peak at 360 nm is about 400 000 counts. The black plot is with no filter and the dark blue plot is with a 280 nm cut off Schott filter in the input light path. The signal below 280 nm is the same with and without the cut-off filter, showing that there is no signal from the sun-bed lamps in this wavelength region. This enables the region between 250 and 270 nm to be used as an estimate of the stray light above 270 nm. The fitted red line is used as a baseline for calculations using the spectrum. Results using this correction agree reasonably well with transfer calibrations from Figure 1 measurements using a lamp identical to the ones in the Auckland bed by both a NIWA standard solar spectrometer and the miniature spectrometer.

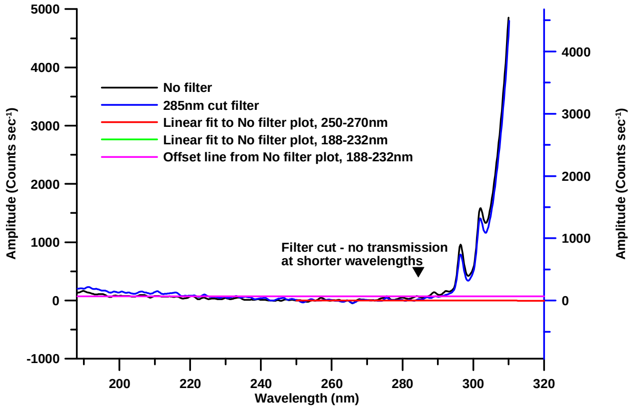


Figure 1. Effect of stray light in the UVB region.

Solaria used in the vitamin-D project

Two locations, Dr. Wishart's Phototherapy Clinic in Auckland and the Moana Pool in Dunedin were used for the controlled UV exposure of some subjects in the vitamin-D project. The calibration of the solaria was an essential part of determining the length of exposure. Table 1 shows the technical details of each solarium.

Table 1. Technical details of the four solaria used.

Location	Designation	Tubes
Auckland Dr Wishart	UV-A chamber Daavlin	36 x Light Sources F72 T12 BL-HO
Auckland Dr Wishart	UV-B chamber Daavlin Spectra 726-SP-2X	24 x Philips 'TL' UV-B
Dunedin Moana Pool	Hapro Luxura Newer Blue bed	26 x 100 W R Maxlight + face
Dunedin Moana Pool	Older Cream bed	24 x 100 W Cosmedico Brilliant + face

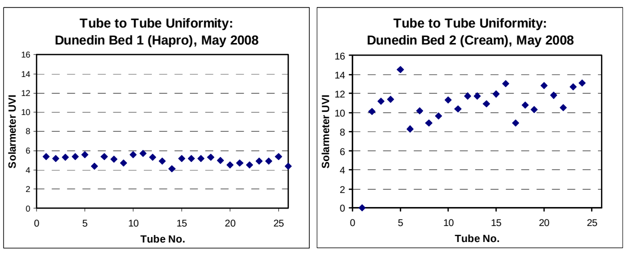


Figure 2. Tube to tube uniformity in two sunbeds.

Uniformity and stability of Dunedin solaria

The spatial and temporal uniformity of the sunbeds was measured using a hand-held solar meter. This gives a relative scale because the solar meter is designed for measuring solar spectra. Results are shown in Figure 2, and in Tables 2 and 3.

Table 2. Longitudinal uniformity along two sunbeds.

•	• 0.5 m (leg)		• 1.0 m (waist)		• 1.5 m (chest)	
Mean	Lower	Upper	• Lower	• Upper	• Lower	• Upper
Bed 1	5.6	5.7	• 5.6	• 6.0	• 6.6	• 6.1
Bed 2	12.1	11.5	• 12.6	• 12.1	• 13.0	• 12.4

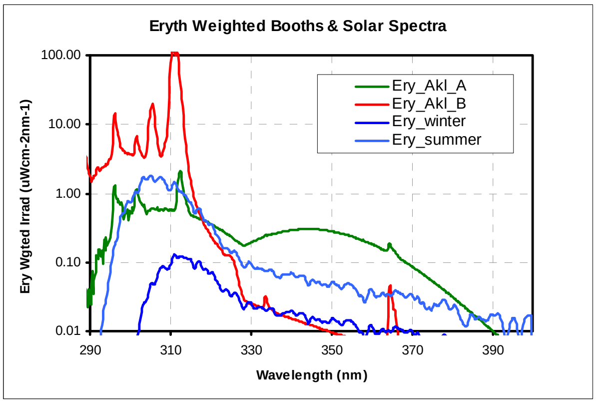
Table 3. Temporal changes derived from at least 5 measurements over the 2-year study period.

Sunbed	RMS %
Auckland UV-A Chamber	1.4
Auckland UV-B Chamber	5.5
Dunedin Bed 1 (Hapro)	7.3
Dunedin Bed 2 (Cream)	3.0

Comparing sunbed and solar spectra

Figure 3 compares weighted irradiances from the Auckland beds with those from typical summer and winter solar spectra. Note the logarithmic scale used on the y-axis. Unweighted spectra, and action spectra for vitamin D production and erythema are shown in the accompanying paper by McKenzie et al. Conspicuous in these plots is the larger irradiance of the UVA solaria in the 320–380 nm region and the UVB solaria in the 300–320 nm region, compared with the summer solar spectrum.

Table 4 summarises the results of all sunbed measurements. Ratios of vitamin D weighted irradiance to erythemal weighted irradiance represent the "Efficiency" of producing vitamin D, based on the currently accepted action spectra for the production of vitamin D and erythema. Higher efficiency means higher vitamin D production for a given erythemal irradiance. Based on the currently accepted action spectra for vitamin D production and erythema, most sunbeds are not as efficient as summer sunlight in producing vitamin D. According to this definition, their efficiency should be approximately the same as for winter sunlight.



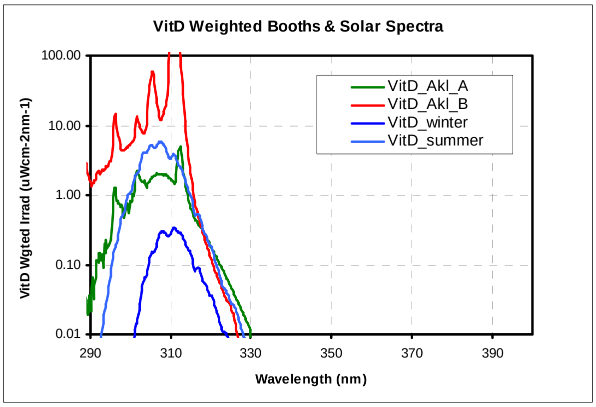


Figure 3. Spectra weighted by the action spectrum for erythema (upper panel) and vitamin D production (lower panel) from sunbeds compared with sunlight.

Table 4. Comparison between sunbeds and sunlight. Weighted irradiance values have units of µWcm^{-2}.
t(2 SED) is the time in minutes to achieve an exposure of 2 SED (i.e., 200 Wm^{-2} of erythemally weighted UV, which approximates one minimum erythemal dose (MED) for sensitive skin.

	Akl_ Bed A	Akl Bed B	Dun Bed 2	Dun Bed 1	Winter Sun	Summer Sun
UVA	17515	1527	11484	11147	1797	6162
UVB	156.9	5544.9	193.8	67.0	17.9	206.6
UV_{Ery}	30.0	408.1	28.8	13.8	2.6	28.2
UV_{VitD}	34.8	997.4	42.1	14.8	3.2	56.7
UVI	12.0	163.3	11.5	5.5	1.0	11.3
t(2SED)	11.1	0.8	11.6	24.1	128.1	11.8
VitD/Ery	1.16	2.44	1.46	1.07	1.22	2.01
%UVB	0.89	78.41	1.66	0.60	0.99	3.25

Erythema versus vitamin D production from sunlight and solaria

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Robert Scragg[1], Alistair Stewart[1], and John Wishart[2]

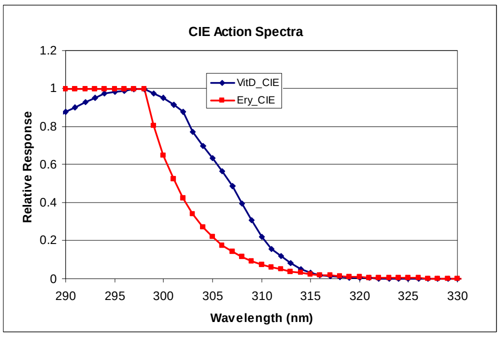
Abstract. We compare production rates of vitamin D as a function of sun-burning radiation for two types of dermatological UV chambers, and for summer and winter sunlight. The main results presented here are based on experimental studies where the blood serum vitamin D of participants is measured before and after receiving multiple doses of UV radiation from two different UV booths. The relative increases in vitamin D between different lamps are inconsistent with the action spectrum for vitamin D published by the CIE, and suggest that the true action spectrum is confined to shorter wavelengths in the UV region. However, further measurements with low doses from each lamp are needed to verify that hypothesis. However, see **addendum** below..

Introduction

A substantial contribution to our knowledge of the photochemical production of vitamin D has arisen from work carried out by Holick and his co-workers at Boston (42° N) since the 1980s. In addition to deriving the action spectrum for vitamin D production that was recently adopted by the CIE (Bouillon et al. 2006), they have also shown that in summer at noon (UVI > 10), sufficient vitamin D is produced in fair skinned individuals after ~1 minute of full body exposure to sunlight, or ~10 minutes if just the hands and face are exposed, but that no vitamin D is produced during the winter months at mid-latitude sites such as Boston (when UVI < 2) (Webb et al. 1988). However, a recent study has challenged these findings (McKenzie et al. 2009). Using spectral measurements taken at Lauder New Zealand (45° S), it was found that some vitamin D should be produced when UV intensities are similar to the Boston winter.

Spectral distributions and weighted irradiances

Figure 1 shows the action spectra for erythema (McKinlay & Diffey 1987) and vitamin D production (Bouillon et al. 2006), as published by the CIE. The lower panel shows the ratio of these two weighting functions. For wavelengths less than 298 nm or greater than 317 nm the ratio is less than one. But its peak value, near 308 nm, is nearly 3.5. Consequently, a monochromatic source centred at 308 nm would produce approximately twice as much vitamin D per unit of sun burning radiation as a monochromatic source centred near 301 nm or 313.5 nm; or four times as much as a monochromatic source centred at 317 nm. Here we compare the measured and calculated ratios of vitamin D production per unit of sun burning radiation for different sources: $R = UV_{VitD}/UV_{Ery}$, and find that the measured responses are inconsistent with those calculated.



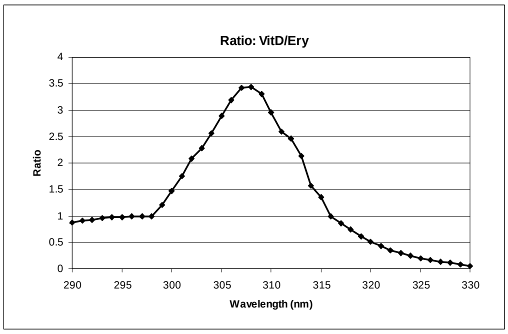


Figure 1. The upper panel shows the action spectra for erythema and vitamin D production as published by the CIE. The lower panel shows their ratio.

Table 1. Comparison of weighted irradiances and derived parameters from the two UV booths compared with sunlight at 45S in winter and summer.

Parameter	Bed A	Bed B	Winter Sun	Summer Sun
UV_{Ery} (μWcm^{-2})	30.0	408.1	2.6	28.2
UV_{VitD} (μWcm^{-2})	34.8	997.4	3.2	56.7
$UVI = 0.4xUV_{Ery}$	12.0	163.3	1.0	11.3
Mins for 2SED	11.1	0.8	128.1	11.8
$R = UV_{VitD}/UV_{Ery}$	1.16	2.44	1.22	2.01

Study method

The study relates to UV exposures undertaken in phototherapy booths at a dermatological clinic in Auckland during the winters of 2006 and 2007 when ambient solar UV levels were low (McKenzie et al. 2006). Participants were randomly assigned to receive regular twice-weekly sub-erythemal UV exposures from the phototherapy booths designated "Bed A" (62 participants), or "Bed B" (59 participants). The spectral distribution of Bed A is similar to that from a range of sun beds in

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common use in New Zealand. The spectrum of Bed B, which is especially designed for dermatological use, is dominated by a strong emission at 311 nm.

Doses from Bed A were relatively low, as this was originally intended as a control. On the other hand, doses from bed B were as large as practicable without inducing erythema, and were generally increased from week to week (i.e., but always less than 1 MED[3] per session). The cumulative dose over the 12-week period varied according to skin type, but was on average 11 SED from Bed A and 174 SED from Bed B.

Table 2. Calculated and measured ratios of vitamin D production per SED of UV exposure.

Parameter	Period 1. Six Weeks		Period 2. 12 Weeks	
	Bed A	Bed B	Bed A	Bed B
R (Calculated, from UV spectra)	1.16	2.44	1.22	2.01
R (Measured, from ΔVitD)	4.5 ± 0.3	1.0 ± 0.1	3.1 ± 0.3	0.4 ± 0.1

Blood serum vitamin D was measured at the start of the study, then at the end of a 6 week period in which 12 UV exposures were administered, and again at the end of a second 6-week period after a further 12 UV exposures.

Spectral irradiances from the beds are compared with those for noon sunlight in summer and winter in Figure 2, and the weighted irradiances are compared in Table 1. The calculated sensitivity of vitamin D production per SED for Bed B (R_B) is approximately twice R_A. Coincidentally, the sensitivity value for Bed B is similar to summer sunlight whereas the value for Bed A is similar to winter sunlight.

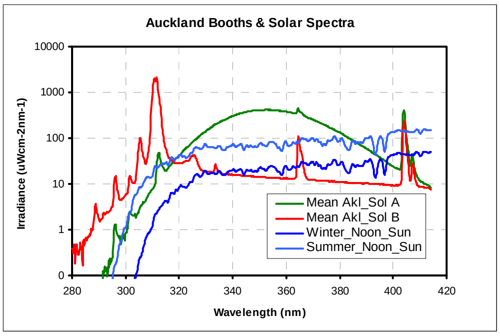

Figure 2. Spectral irradiances of two UV booths in Auckland, compared with mid-latitude irradiances measured under clear skies at noon in summer and winter.

Changes in vitamin D status due to the lamp exposures were calculated, including a subtraction of the population-average seasonal pattern in blood serum vitamin D. Inclusion of this term represents the assumption that apart from sun bed use, the study group was typical in its UV and dietary behaviour. These results were expressed in terms of the change in vitamin D per SED, as shown in Table 2. Note that whereas the calculated sensitivities are greater for Bed B, the measured sensitivities are greater for Bed A.

Contrary to expectations based on the measured changes in vitamin D status, the efficiency of vitamin D production from Bed A appears to be much more than Bed B per SED. Some of the discrepancy is attributable to non-linearities in production, as evidenced by the fact that the sensitivity in the second 6-week period, where UV intensities were increased, was smaller than in the first period, especially for Bed B where the erythemal doses administered were much larger.

Table 3. Comparing calculated and measured efficiencies of vitamin D production per SED for the two beds.

Parameter	6 Wk	12 wk
R_B/R_A (Calc from UV spectra)	2.10 ± 0.05	1.65 ± 0.03
R_B/R_A (Meas from ΔVitD)	0.22 ± 0.03	0.13 ± 0.02
Calc/Meas	9.5 ± 1.2	12.7 ± 1.6

Table 3 shows there is more than a factor of 8 difference between observation and theory for period 1, and an even greater difference for period 2. Huge non-linearities in vitamin D production for dose ~1 SED or as yet unresolved temperature effects would be required to resolve the discrepancy. Analysis of data from a follow-up study where similar UV doses were administered from each bed should help resolve these issues. These discrepancies would be reduced by a factor of two if the new action spectrum for vitamin D production (Olds et al. 2010) were used instead of the CIE action spectrum.

Addendum. After presentation of this material at the UV Workshop, subsequent analysis of data from the sun beds discussed here (which were also used in our HRC UV-Vitamin D study) showed that the production of vitamin D from these sun beds, was much less than as stated during the presentation. The error was due to an incorrect calibration factor which has now been corrected in this version. With these corrected values, the discrepancy between theory and measurement is reduced slightly.

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[3] 1 SED = 1 Standard Erythemal Dose = 100 Jm^{-2} of erythemally-weighted irradiance. For sensitive skins, one Minimum Erythemal Dose (MED) is approximately 2 SED. For less sensitive skins, 1 MED can exceed 10 SED.

The introduction of compact fluorescent lights (CFLs) and the impact of UVR emissions on photosensitive people

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Abstract. In 2008 the Australian Government decided to phase-out inefficient incandescent lights and replace them with a more cost effective and efficient alternative, energy saving compact fluorescent lights (CFLs). The replacement of incandescent lights has benefits to the community and the environment. CFLs use only about 20% of the electricity to produce the same amount of light as conventional incandescent lights. The use of less energy reduces the amount of greenhouse gas emissions and has the potential to lower the cost of electricity which benefits both individuals and industry whilst helping the environment.

Ultraviolet radiation (UVR) can exacerbate skin conditions for people who are photosensitive to UVR. These people are advised to minimise their exposure to solar radiation and avoid solaria. With an increase in CFLs in the home, there is a need to quantify the UVR and visible emissions from CFLs commercially available in Australia. ARPANSA has measured a number of lamps: incandescent, halogen and CFLs. In all, ARPANSA tested 26 different CFLs covering most of the well known brands (Philips, Nelson, GE, Megaman and Mirabella) including singles and double envelope lamps ranging from 5W to 28W. For comparison, 12 incandescent globes (40W to 100W) and 2 halogen globes (100W) were also tested. The results show that at 10 cm all the light sources emit some UVB and UVA radiation. The study also clearly shows the intensity from the lamps decreased rapidly with distance.

Introduction

With current controversy over climate change the Australian Government believes that lighting efficiency presents opportunities where significant energy savings can be made. CFLs work on the same principle as linear fluorescent lights commonly found in the ceilings of offices. They contain a small amount of mercury which generates UVR emissions that excite the phosphor coating on the inside of the glass envelope to emit visible light. There should be a 100% conversion of the UVR to visible light; however, some UVR is transmitted due to defects in the phosphor coating of the glass envelope.

A study by (Khazova et al. 2008) measured the UVR and visible emissions from 73 CFLs (20 single envelope and 53 double envelope CFLs) at 2 cm and 20 cm. They found that the double envelope (DE) CFLs had very low UVB emissions whilst single envelope lamps emitted in the UVB and UVC. The UVC emissions were probably due to defects in the phosphor coating of the glass envelope. They concluded that damage to the eye at 20 cm or closer is unlikely due to the eye's aversion to bright light and long-term skin exposure at close distances from CFLs may be a risk with single envelope (SE) CFLs.

Figure 1. Two single and a double envelope compact fluorescent lamps.

There are people who are photosensitive to UVR and visible light, e.g., people who suffer from lupus and other light sensitive conditions may be affected by the emissions from CFLs.

A recent study by (Klein et al. 2009) found that even though the levels emitted by CFLs are very low, the exposure times can be long, which may result in high cumulative exposure. The erythemal limits are well known for people who are not photosensitive to UVR; however, it is difficult to quantify any exposure limits for photosensitive people. This makes it difficult to provide advice to photosensitive people, so the use of low power (DE) CFLs that emit the lowest levels of UVR are recommended.

Results and discussion

Figure 1 shows examples of the lamps tested by ARPANSA; they are commercially available tubular or coiled CFLs and an encapsulated CFL which has an outer plastic envelope. In Figure 2 the spectral energy distributions for incandescent, halogen and the CFL lights are shown. The minimum and maximum UVC, UVB, UVA, UVR, blue light emissions and T_{ery} (CIE 1987) for each category of lamp are shown in Table 1. Energy saving CFLs emit UVB, UVA and traces of UVC radiation. The results in Table 1 show that (DE) CFLs with their plastic diffuser serve as a shield and further attenuate UVR. UVR from a (SE) CFL which does not have an outer shield are significantly higher, but would still only be a fraction of the exposure to solar UVR. The time required to achieve an erythemal dose

(T_{ery}) for a 20W (SE) CFL was 7 hours of continuous exposure at 10 cm to produce erythema (skin reddening) for a person with skin type I. This is equivalent to 11 minutes of direct exposure at solar noon in Melbourne during summer.

Artificial lamps are a major source of blue light which can affect some photosensitive people. Incandescent lamps produce the lowest blue light intensity whilst the (SE) CFLs emit the highest. (DE) CFLs emit lower levels of blue light than (SE) CFLs. The halogen lamps have higher blue light levels than incandescent or (DE) CFLs but less than (SE) CFLs.

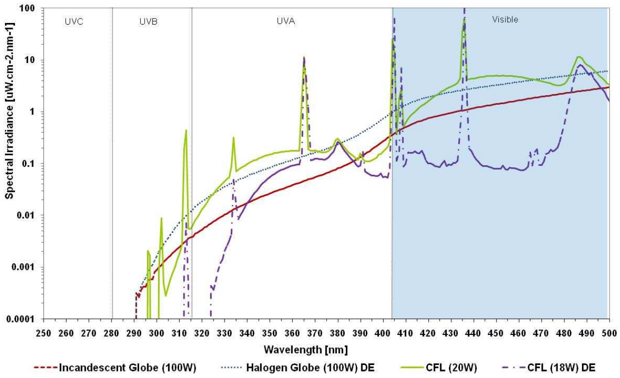

Figure 2. UVR and visible spectra of incandescent, halogen, single envelope (SE), and double envelope (DE) CFLs on a log scale. For comparison the lamps have comparable power outputs.

UVA levels tend to be high for CFL lamps due to the strong emission at 365 nm. Again, the UVA level is lower for the (DE) CFLs than the other lamps due to the outer envelope. The (SE) CFLs has significantly higher UVA and UVB than the other lamps. The (DE) CFLs emit lower UVR than (SE) CFLs; however, most people especially those who are photosensitive to UVR may not know that a (DE) is needed to further reduce the UVR levels emitted by CFLs. The UVR levels for halogen lamps tend to be higher than incandescent and (DE) CFLs and less than (SE) CFLs. The (DE) CFL has an erythemal exposure time (T_{ery}) measured at 10 cm of 609 hours, significantly higher than (SE) CFLs of 114 hours.

Conclusions

All the lights tested emitted some UVR.

- The (SE) CFLs emitted the highest UVB and UVA, more than incandescent or (DE) CFLs.
- The (DE) CFLs emitted less UVB than incandescent lamps.
- The incandescent lamps emitted the least amount of blue light followed by the (DE) CFLs.
- People who are photosensitive to UVR and blue light should only use (DE) CFLs at distances greater than 25 cm.
- Low UVR emitting (DE) CFLs are available, but it is difficult for photosensitive people to know which (DE) CFLs have the lowest UVR emissions. We are currently working with DEWHA to assess the lowest UVR and blue light emissions from a variety of (DE) CFLs.

Acknowledgment

We thank the Department of Environment, Water, Heritage and the Arts (DEWHA).

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Table 1. The UVC, UVB, UVA, UVR and blue light maximum and minimum intensity levels and the CIE weighted (T_{ery}) results for a group of lamps with similar power outputs of 100W. Value in the brackets is the incandescent equivalent.

Sources	Emissions	UVC 250-280nm μWcm^{-2}	UVB 280-315nm μWcm^{-2}	UVA 315-400nm μWcm^{-2}	UVR 250-400nm μWcm^{-2}	Blue Light 400-495nm μWcm^{-2}	CIE T_{ery} hrs
Incandescent							
100W Frosted Softone	minimum	0.0E+00	3.6E-02	5.0	5.0	136	521
100W Clear Softone	maximum	0.0E+00	2.3E-01	21.7	21.9	160	81
Halogen							
100W Frosted Brilliant	minimum	0.0E+00	9.5E-02	14.6	14.7	312	240
100W Clear Brilliant	maximum	0.0E+00	5.9E-01	50.5	51.2	318	37
CFLs (SE)							
20W (100W) Natural Colour	minimum	0.0E+00	6.7E-01	26.9	27.6	501	114
20W (100W) Warm White	maximum	3.3E-03	9.8	62.7	72.5	289	7
CFLs (DE)							
18W (100W) Warm White	minimum	0.0E+00	8.6E-03	22.5	22.5	266	609
14W (75W) Warm White	maximum	6.9E-04	1.7E-01	19.3	19.5	202	333

Solaria in Australia and the standards making process

Peter Gies[1], John Javorniczky[1], Stuart Henderson[1], Alan McLennan[1], Colin Roy[1], Jordan Lock[1], Claire Lynga[1], Alan Melbourne[1] and Louisa Gordon[2]

Abstract. As a result of a compromise between the solarium industry and health agencies, the 2002 standard on solaria for Australia and New Zealand (AS/NZS 2635:2002) left the upper limit of allowed emissions at UV Index 60. To aid in the deliberations of the standards committee preparing the new standard, ARPANSA researchers made measurements of a number of solaria to assess the range of intensities emitted. Twenty solaria were examined in detail. Of these, only one solarium had emissions of less intensity than UV Index 12, typical of mid latitude summer sunlight and the maximum allowed for solaria in the European Community, while three solaria emitted at intensities above UV Index 36. As a result, the upper limit on solaria emissions was reduced to UV Index 36 in the 2008 standard (AS/NZS 2635:2008).

Introduction

Media attention following the death in Australia of a young solarium user due to melanoma in 2007 put the solarium industry and the solarium standard (AS/NZS 2635: 2002) in the spotlight, and as result the standard on solaria was reopened in 2008. Numerous research studies had shown that many of the recommendations for solaria were not being complied with and concluded that self regulation of the solarium industry was clearly not working (Paul et al. 2005; Team et al. 2006; Dobbinson et al. 2006). The International Agency on Research on Cancer (IARC 2006) also reported the first evidence that long-term use of sun beds was positively associated with melanoma and that first exposure to sun beds before age 35 significantly increased risk of melanoma.

In the light of this new evidence, it became obvious that the 2002 solarium Standard had a number of elements that required updating, e.g., skin types, age limits, operator training etc, but particularly the allowed upper limit of UVR emissions of UV Index 60, five times as strong as typical mid latitude summer sunshine. Standards Australia and New Zealand require the various parties on the committee, such as the solarium industry, health agencies and consumer organisations to reach consensus. If one of the parties does not vote for the standard, then there can be no new standard. The solarium industry was prepared to consider reducing the allowed upper limit of UVR emissions for solaria from UV index 60, as long as this did not entail major reconfiguration of sun beds at substantial cost to the industry. The solarium industry would not consider revising down to the current EC limit for the maximum intensity of UV Index 12. The question was: what were current solaria emitting? ARPANSA agreed to survey as many solaria as possible and report back to the committee.

In 2007, ARPANSA contracted QIMR to do a report on health impacts of regulation of solaria, (Gordon et al. 2007) and also organised a National Forum on Solaria in November 2007 which brought together state regulators, along with other stakeholders such as the Cancer Council Australia, the solarium industry and public health representatives. The ARPANSA forum came up with a set of basic requirements for solaria regulations e.g., prohibition on persons under 18 years of age using sun-tanning units; all exposures to sun-tanning units to be subject to supervision by an operator; all persons supervising the operation of sun-tanning units to be trained; only such trained persons to determine and control exposures; skin type to be assessed by operators and persons with skin type 1 to be prohibited from using sun-tanning units; clients to provide written consent before using a sun-tanning unit; and specified limit on exposure in an individual session and on minimum times (48 hours) between successive sessions. The outcomes of the forum were used by the Radiation Health Committee to develop uniform regulatory proposals for inclusion in the National Directory for Radiation Protection and adoption by all states and territories. The full details are available at http://www.arpansa.gov.au /pubs /comment/dr_ndrp4.pdf

Selection of solaria

ARPANSA undertook to survey the outputs of as many commercial solaria as possible before the Standards committee was required to finalise the standard. Solaria were selected in consultation with the various solarium industry representatives on the Standards committee to include as many different types of sun beds and lamps as possible. Solarium establishments in Sydney and Melbourne were selected, as ARPANSA has offices in both cities and there were large numbers of operating solaria within 10–20 km. A typical visit involved 3 to 4 ARPANSA staff along with at least two spectrometers and a number of handheld UV meters.

Measurement equipment

Measurements of the spectral emissions from solaria were made with two systems; the first was a Bentham TM300 double monochromator system, which can cover the UVR and part of the visible spectral wavelength range from 200 to 600 nm at 1 nm intervals with a bandwidth of 1 nm. The input optics consisted of a cosine-corrected Teflon diffuser with 2 metre fibre optic cable and a bi-alkali end-window photomultiplier. Scans of the solarium output were done from 250 to 400 nm at 1 nm steps. The second measurement system was an Ocean Optics USB 4000 3648 element Toshiba linear CCD array. Spectral wavelength range was across the UVR and visible from 250 to 850 nm and the input optics were a cosine corrected Spectralon diffusing fibre optic irradiance probe. Both instruments were calibrated against deuterium and quartz tungsten halogen standard lamps traceable to the

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CSIRO Australian National Measurement Institute at Lindfield, New South Wales. Wavelength drift was checked with a Hg pencil lamp.

Results

The intensities of UVR being emitted by the 20 solaria examined ranged from a minimum of UV Index 10.1 up to a maximum of UV Index 48, with only three solaria emitting more than UV Index 36. The distribution of maximum intensities is shown in Table 1. Although a limit of UV Index 30 was briefly considered, the solarium industry was not prepared to reduce the limit this far, even though only five of the twenty solaria had measured outputs of greater than UV Index 30. The Standards committee then managed to agree on a compromise upper limit of UV Index 36.

Table 1. The distribution of UVR emissions from solaria in terms of UV Index.

UV Index	<12	12 – 24	24 – 36	> 36
No.	1	10	6	3

Solarium operators generally do not know what the intensity of their solaria are in real terms, either UV index or $W.m^{-2}$. The solarium industry classes sun beds by time e.g., beds are 6 min, 8 min, 10 min, etc. However, at one establishment, the three 8 min sun beds differed in intensity by 55%, with UV Index values of 31.3, 40.7 and 48.6, which meant 8 min UV doses ranged from 3.8, 4.9 and 5.8 SEDs, a very substantial variation and one that could easily result in overexposure of clients. This raises the question of whether there is a pathway for reporting overexposures built into the regulation process?

While the % UVB emissions from the solaria were less than found in sunlight (5.8%), the actual UVB emissions in $W.m^{-2}$ were higher than those found in sunlight for 14 of the 20 solaria. These solaria therefore had more UVA and more intense UVB than sunlight (CIE 172, 2006).

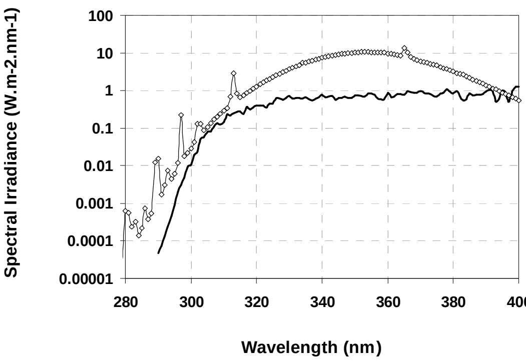

Figure 1. A comparison of the emission from a solarium (○) against the solar spectrum (--) on a log scale, with the solarium clearly a factor of 10 higher in parts of the UVA region, while also being higher across most of the UVB.

Gordon et al. (2008) studied the impact of solaria in terms of the numbers of new melanoma cases and melanoma-related deaths attributable to solarium use by younger people in the five most populous Australian states, taking into account the local state levels of solar UVR The study concluded that by successfully enforcing solarium regulations that ban use by people younger than 18 years or with fair skin, favourable health and cost benefits could be expected. State regulations governing solaria have been enacted in Victoria, South Australia, Queensland and Western Australia in 2008, followed by New South Wales and Tasmania in 2009. ARPANSA's National Directory for Radiation Protection will help to ensure future national uniformity of regulations.

Conclusions

1. Solaria emissions ranged from UV Index 10 to 48, achieved with high UVA outputs but low % UVB
2. Despite low % UVB, most solaria emitted more UVB than found in mid-latitude summer sunlight
3. UVR emissions from solaria in Australia are the highest so far reported in the world.
4. Compliance with the recommendations of IARC would minimize adverse health effects.
5. Regulation of solaria by states should help to ensure these recommendations are complied with.
6. Improved public education is also required and should be continued into the future.

Acknowledgments

Thanks to the staff of the ARPANSA UVR Section and the Regulation Branch who assisted with the measurements. Thanks also to the members of the Solarium Industry Groups on the Standards Committee who kindly made their solaria available for measurement.

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Sun bed policy: an international perspective

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Abstract. Artificial tanning sun beds continue to be popular despite the weight of evidence showing a link between sun bed use and melanoma. In recent years there has been considerable movement by governments at a state and national level in Australia, Europe and the USA to introduce regulations to control the use of and access by young people to artificial tanning sun beds. A key opportunity exists to ride this tide of momentum to lobby hard for the introduction of legislation to control youth access to sun beds and to ensure all consumers are adequately informed of the risks. An important part of this process will be to monitor the impact of any legislation to ensure it doesn't lead to increased consumer confidence in the safety of their sun bed experience and that appropriate compliance and enforcement checks and are put in place.

Size of the problem

A systematic review by the International Agency for Research on Cancer found a 75% increased risk between ever using a sun bed before the age of 35 and melanoma (International Agency for Research on Cancer Working Group on artificial ultraviolet light and skin cancer, 2007). A more recent review by the Queensland Institute of Medical Research found an almost two fold increased risk (Gordon & Hirst 2007). The same report stated that sun beds caused 281 cases of melanoma a year in Australia, killing 43, and were responsible for 2572 squamous cell carcinomas.

Over the last three decades, there has been substantial growth and continued high usage by the general public of artificial tanning sun beds worldwide. Indoor tanning is widely practised in mostly developed countries, particularly in Northern Europe and the United States.

Before 1980, less than 5% of the adult population in Belgium, France and Germany had used an artificial tanning sun bed; by 1995, this had grown to 33% (Autier et al. 1994). Similar patronage figures are found in the United States (Demko et al. 2003). In Sweden the figure has been as high as 70% of adolescents reporting sun bed use (Boldeman et al. 2003). Sun bed users are typically young females, have a parent or care giver who has used a sun bed and are least likely to use a SPS 15+ sunscreen by the beach or pool (Cokkinides et al. 2002).

Countries with legislative controls

The number of countries that have implemented controls to manage the health risks associated with sun bed use has grown significantly in recent years. The most outstanding achievement has been the total outright ban of sun beds, except for use for medicinal purposes, in Brazil that came into effect in November 2009.

In the United States 31 states have passed regulations relating to sun beds. Some US states, such as California, Delaware and Texas, allow under 18 access only with parental permission and being present on the first visit. However, to date no US state has totally restricted under 18 access as per WHO recommendations. A new 10% tax on indoor tanning services that will be introduced in July 2010 will likely have a significant effect on the sun bed industry in the US. Unfortunately, US studies on compliance with regulations in New York, North Carolina and San Diego have shown vast non-compliance (Fairchild & Gemson 1992, Hornung et al. 2003). The San Diego study showed that 95% of facilities were not in compliance with current regulations relating to tanning schedules (Kwon et al. 2002).

In the European Union, France, Belgium, Germany, Scotland, Spain, and Portugal all now restrict use of sun beds for persons under age 18. The United Kingdom is expected to follow shortly. A similar under-18 ban is also in place in most Australian states.

In Victoria, Australia, in addition to banning all those under the age of 18, each sun bed operator must have a licence to operate and each sun bed is registered with the Victorian Government. Warning signs are required to be installed in each sun bed booth and each new client to a solarium must sign a client consent form that outlines the risks associated with sun bed use, particularly in relation to the increased risk of skin cancer. Heavy penalties of up to almost AUD$1million are in place and enforcement officers have gone to every solarium in the state since the legislation was implemented two years ago. The good news is that the Victorian Government has publicly stated that the number of solarium establishments has declined by over 45% since legislation was implemented. The contribution of increased awareness combined with legislation and strong enforcement has without doubt contributed to this significant reduction in the number of sun bed outlets in the state.

According to the World Health Organization (WHO), there are clear directions in terms of what should be expected in terms of regulations for the control of sun bed operations (Sinclair 2003). This includes restricting access to those under the age of 18, ensuring warning notices are placed in all cubicles and in the foyer area, ensuring all new clients to the establishment are aware of the risks by signing a consent form as well as ensuring all operators are adequately trained. The WHO has made a clear recommendation that governments should consider comprehensive legislation in relation to sun bed use and if licensing of operators is to occur, they should ensure they are not recognised by the general public to be government endorsed as compared to unlicensed operators (Sinclair 2003).

Some success has been achieved in improving sun bed operator standards through the use of trade practice legislation relating to false and misleading advertising such as unsupported claims that sun beds are 'safe' and 'healthy'. Trade practice legislation has worked successfully in Australia to motivate changes in sun bed operator practice when individual operators were brought to the attention of authorities for providing false and misleading information to consumers (Australian Competition and Consumer Commission, 2008).

Ideally, however, rather than rely on broad consumer protection legislation, it is preferable to introduce specific legislative controls of the sun bed industry that provide strong enforcement and significant penalties for breaches. The priority for legislation should be to ensure all minors under the age of 18 are restricted from gaining access to sun beds, and any unsupervised sun bed operations are banned.

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Photoageing – what is it all about?

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Abstract. Photoageing is the addition of chronic UV-induced damage to intrinsic chronological ageing. The three main clinical aspects of photoageing are skin cancers (Figure 1), photoatrophy (Figure 2) and cosmetic concerns. The mechanisms of photoageing include: activation of skin cell surface receptors by reactive oxygen species (ROS), leading to stimulation of stress-associated mitogen-activated protein; ROS mediated damage to membrane lipids leading to ceramide release and generation of prostacyclins; increased transcription of AP-1 and down regulation of TGF-β, resulting in loss of collagen; induction of various pro-inflammatory cytokines; damage to mitochondrial DNA, leading to reduced ability to generate energy; damage to dermal proteins; and shortening of telomeres, leading to apoptosis and early senescence.

Figure 1. Malignant melanoma.

Mechanism

Within minutes of UV exposure, even as little as 1/10th of an MED (minimal erythema dose), reactive oxygen species are produced in the skin. These can activate skin cell receptors, such as epidermal growth factor (EGF), keratinocyte growth factor, tumour necrosis factor (TNF-α), and interleukin-1 (IL-1). This leads to stimulation of stress-associated mitogen-activated protein (MAP) kinases, which in turn, induce transcription of AP-1. AP-1 interferes with the synthesis of dermal collagen.

In addition, ROS have a direct damaging effect on membrane lipids leading to release of ceramides (reducing the skin barrier function of the skin), which may then be converted into pro-inflammatory prostaglandins.

Furthermore, UV interferes with the signalling of TGF-β, which is needed for both the formation of collagen, and helps prevent keratinocyte proliferation. With the addition of the effect of UV on nuclear factor-kb transcription factor, there is a marked increase in pro-inflammatory cytokines such as IL-1, IL-6, vascular endothelial growth factor (VEGF) and THF-β.

Figure 2. Photoatrophy of the arm.

The above then stimulates the activity of several matrix metalloproteinases (MMPs) and elastases, which degrade collagen and elastic fibres (Figure 3).

DNA is hypothesised to be the chromophore for the delayed erythema associated with UVB, whereas the responsible chromophore for UVA-induced erythema is not known.

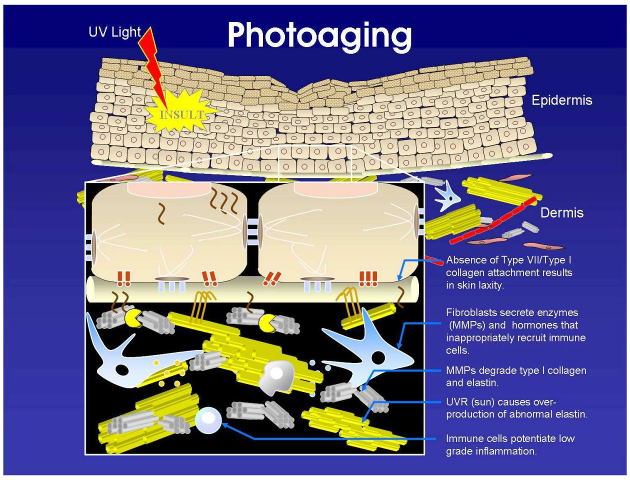

Figure 3. Effect of UV light on collagen metabolism.

UV light induces several different types of DNA damage in a wavelength-dependent manner, such as pyrimidine dimers and oxidative guanine base modifications. Short-term effects of UV include inflammatory infiltrates, vasodilation, formation of sunburn cells, depletion of Langerhans cells, acanthosis and hyperkeratosis. On the molecular level, UV exposure induces stress proteins, and effects both repair processes and cytokine production, such that cells either undergo apoptosis or cease proliferating (cell cycle arrest) in order to undergo repair. Mitochondrial DNA (mDNA) is also damaged by ROS affecting their ability to generate energy.

UVA is a major contributor to protein oxidation in the skin. This leads to inhibition of proteasomal functions and the ability of the cell to successfully degrade additional damaged proteins, particularly in the dermis.

UV radiation (UVR) also affects telomeres. Telomeres cap the terminal portion of chromosomes, preventing their fusion. As chromosomes age, they lose 1–200 terminal base pairs with each cell division. Once the telomere reaches a critical short length, the cell will no longer divide and enters senescence (early cell death).

Prevention and treatment

Sunscreens are the first line of defence against UV irradiation. Smoking accelerates most aspects of UV induced damage. Therefore key elements of prevention of photoageing are sun protection and never smoking.

As photoageing is in part due to UV-induced DNA damage, delivery of enzymes that repair DNA damage may prove to be a useful treatment of photoageing.

The skin contains many antioxidant enzymes (superoxide dismutases, catalases, glutathione peroxidase) as well as non-enzymatic antioxidants (vitamin C and E, Q10, carotenoids), but these become less efficient with age. Various studies have attempted to increase endogenous antioxidant levels with topical and oral antioxidants.

Several studies suggest that low-fat diet confers some protection against the development of actinic keratosis, a UV-induced pre-malignant dysplasia.

Retinoids and alpha-hydroxy acids have been shown to have some beneficial anti-photageing affects (Figure 4).

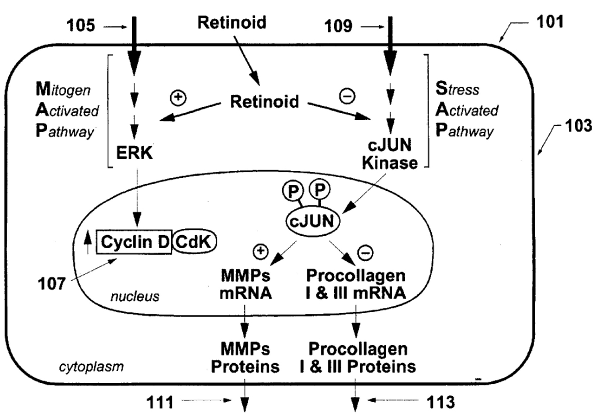

Figure 4. Effect of retinoids on collagen formation.

Summary

Photoageing is the addition of chronic UV-induced damage on chronological ageing, and accounts for the majority of age-related changes of skin appearance. Understanding the mechanisms involved allows targeting of specific treatments for both prevention and treatment.

The role of built environment in modifying UV exposure

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Abstract. Despite over a decade of international public programmes to promote environmental shade as a strategy to reduce overexposure to UV, the design and architectural professions have largely not responded to this call. This paper reflects on the case for designing our living environments to provide protection from UV over-exposure. Firstly, the history of the movement is considered. Secondly, key issues influencing the role of designed environments in modifying UV exposure are discussed. Several past initiatives to educate designers on shade design are critiqued and finally conclusions are drawn.

The urgency to take cover

It is important to remember that it was in response to expected increases in UV levels due to ozone depletion that led the World Health Organization (WHO), in 1992, to set up the Intersun programme (WHO 2010). This initiative complied with requirements of Agenda 21. New Zealanders will remember the alarming television advertisements showing an elderly man and his grandson completely shrouded with sun-protective outfits on a deserted beach. The grandfather reminisced fondly of the time before ozone depletion changed the world. This disaster did not happen. Fifteen years later, because of the success of the Montreal Protocol on ozone depletion, UV intensities in many places had levelled off or were declining (UNEP 2007). However, international research into understanding UV, associated health risks, and human behaviours have been valuable in promoting sun-safe behaviours and role of environmental shade.

The role of shade

Studies of vernacular architecture across all cultures reveal a slow evolution of building design in response to both human needs and the local climate (Rudofsky 1972). In traditional Maori architecture, the mahau (or porch) of the whare was a living space orientated east to trap or store the warmth of the morning sun but also to shield the midday summer sun (Mackay 2005). Over the last two centuries, mass migration around the globe has interrupted this slow natural adaption process. Dark-skinned populations in tropical zones have largely stayed put and continue to practice traditional lifestyles which acknowledge the daily high UV levels. However, notably waves of fair-skinned people from northern Europe have migrated to sunnier climes. With the advent of cheap air travel, fair-skinned northern Europeans frequently travel southwards for short sunshine holidays. This is considered a significant factor in a threefold to fivefold increase in their melanoma rates in the last decades (Garbe et al. 2009). In the case of destinations USA and Australasia, migrations have been permanent. New Zealand and Australia have twice the incidence of melanoma compared with countries in Europe and North America (Garbe et al. 2009, MOH 2009). For fair-skinned people, the impact on daily living of mid-summer UVI 12+ intensities (as found in Australasia) is significant in comparison with mid-summer maximums of UVI 6 common in northern Europe and USA. While clothing and sunscreen are suitable for active work and sport, shade is more appropriate for passive activities around the home and in public spaces. However, people must choose to avoid the sun. Long standing skin cancer researcher Prof. Brian Diffey concludes 'the solar ultraviolet to which a person is exposed depends upon the local UV climatology and his or her behaviour ...'(Diffey 2002).

The heliotherapy movement in 1920s Europe initiated a desire for tanned skin (Suren 1925). This fashion continues but the attraction of sun-bathing is not clear. A study of swimming pool sun-bathers suggested the warmth of sun, rather than its tanning effect, is desired (Mackay 2006). In New Zealand, sensible behaviour is not always intuitive. Commonly, cooling sea breezes force people to seek the warmth of the sun, even when UV levels are high (Mackay 2005). In this situation, laminated glass or polycarbonate can be used as shading materials to create UV protective 'warm shade'.

In New Zealand, some adaption of European traditional housing design has occurred to suit the sunnier climate. In 1947, European educated architect Ernst Plishke published a design for a model New Zealand house (Plishke 1947). Living areas opened onto a sun terrace with large sliding doors. The feature was economical in transforming the interior into a verandah. In winter, occupants can use the courtyard or enjoy the heat of the sun indoors. In summer, the indoor space, opened to the exterior, provides shade. This strategy is common in new houses today. Other adaptations are laminated glass and polycarbonate verandahs and outdoor living spaces positioned in different locations around the building for use at different times of the day.

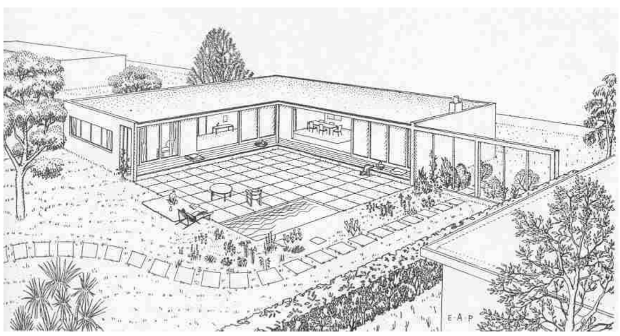

Figure 1. Model house proposal for New Zealand families in 1947.

Shade design education initiatives

Internationally, there have been several initiatives to encourage designers of the built environment to take responsibility for protecting the populace from UV over-exposure, but it is notable that in some countries the drive has not been sustained.

In 1997, the Health Education Authority (HEA) in Britain arranged for the prestigious Bartlett School of Architecture to host a design competition to design shade structures (RIBA 1997). The published designs were stand-alone sculptural objects situated in a park setting. The structures appeared to have no function other than providing various unspecified degrees of UV protection. In the same year, the HEA published a booklet, '*The architecture of shade*', and distributed it to all architectural schools and practices and local councils (New et al. 1997). No reference to sun-shading for UV protection has been identified in UK architectural journals since. In 1998, '*Under cover – Guidelines for shade planning and design'* was published in Australia (Greenwood et al. 1998). In 2000, a New Zealand edition followed and was promoted through a series of Shade Workshops organised by the Cancer Society of NZ (Inc). The presenter, John Greenwood, was a guest at the Canadian Design for Shade 2003 Conference, where 'a number of Toronto sites were re-imagined with a provision of shelter from damaging ultraviolet rays' (Andreae 2003). Again, there is no reference to UV protection in Canadian architectural journals since. Australasian cancer societies have continued to promote sun-shading, especially for schools via Sunsmart Schools programmes. After 2005, CDC published a web-based resource *Shade planning for American schools* (CDC 2009). The guide is focused at a 'grass-roots' level on parents and school management rather than the architects and designers. In 2006, John Greenwood launched 'Web-shade', a computer based shade-audit and design tool.

The author has presented papers on shade research and design to PLEA (Passive Low Energy Architecture) conferences in Chile (2003), Geneva (2006) and Quebec City (2009), as well as to the Society of Building Science Educators in Seattle (2008). Feed-back confirmed that specific design of UV protection is considered relevant only in locations with fair-skinned populations and high levels of UV.

Shade design education recommendations

Education needs to be scientifically valid and use first principles rather than loose generalisations. Shade is useless in isolation and needs to be fully integrated into living environments. A 2009 design and teaching resource for architectural professionals offers an approach centred on assessing the protection factor (PF) of environments as follows (Mackay 2009):

$$\underset{\text{(under shade)}}{\text{PF estimated}} = \frac{1}{\underset{\text{(of shading material)}}{\text{UV transmittance}} \times 0.5 + \text{sky factor}^* \times 0.5}$$

*'*sky factor' is the proportion of the total hemisphere of the sky that can be viewed from a location under the shade.*

The suggested process for considering UV protection in a design project includes the following steps: understanding the science of UV protection and the local climate, researching shading precedents, assessing the out-door occupation requirements (time of day and duration) and the sun-protection needs of the users to determine the protection factor (PF) required for the space and, finally, exploring and testing of alternative designs and confirming estimated PF ratings.

Conclusion

Early initiatives to promote shade design were a response to predicted ozone depletion which has since been avoided. The role of shade in skin cancer prevention was over-emphasised and internationally the architectural professions have not recognised its relevance. In Europe, specific design may not be required (due to relatively low UV levels and static populations). However, in Australasia and probably the southern states of USA (locations with relatively high UV levels and fair-skinned immigrant populations) the in-depth study and application of environmental UV protection has a place.

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Correlates of sun exposure in people aged 45 and older in NSW

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Abstract. Sun exposure is often measured in studies of health outcomes by asking people with a cancer diagnosis and people without this diagnosis about their past behaviour. Rarely do we ask large numbers of 'healthy' people how much time they spent in the sun recently and, at the same time, collect a lot of information about their personal characteristics and their behaviour. The 45 and Up Study in NSW has done that: it is a population-based cohort study of NSW people aged 45 and over who were randomly sampled from Medicare Australia, Australia's universal health insurance system, which includes all Australian citizens and permanent residents (Banks 2008). People in regional and remote areas and people aged 80+ years were over-sampled by a factor of two. Participants completed a mailed self-administered questionnaire and consent form (see http://www.45andUp.org.au). The participation rate was 18%. We examined data from 78,223 people of European ancestry who were aged 45–74 years and who completed the questionnaire between February 2006 and June 2006. We included people to 74 years of age to reduce the range of lifestyle changes over time, such as clothing and sun-related behaviour, that may have influenced their sun exposure. The 45 and Up Study has been approved by the University of New South Wales Human Research Ethics Committee and the Cancer Council New South Wales Ethics Committee.

The 45 and Up study questionnaire

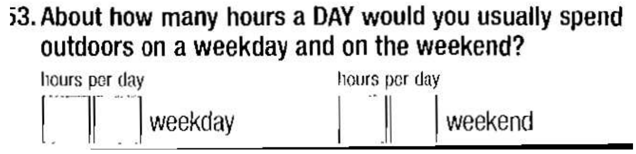
The information in this report was taken from direct questions about outdoor hours, about behaviour considered to be sun-related, and about other factors that might influence sun-related behaviour or cancer risk. For clarity of interpretation, the report excludes participants who reported a personal history of skin cancer of any kind (they answered yes to the question 'has a doctor ever told you that you have a skin cancer' or to the question about any operation to remove a skin cancer, or gave an age at which either of these two events occurred).

Sun exposure and related information

The items selected as relevant in the 45 and Up Study questionnaire are listed here in groups of related variables.

- Personal: Age, sex, height and weight, education (highest qualification), country of birth (COB), ancestry, year arrived in Australia, SES index of residence, language other than English, marital status, household income, work status, age retired, hours paid and unpaid work, being a carer.
- Sun related: Skin colour of inner upper arm, skin reaction on repeated exposure to bright sunlight, UV value taken from current residence.
- Lifestyle related to sun: Current housing, and in last week, times walked, times moderate activity and also times vigorous activity (examples given).
- Lifestyle factors known to cause cancer or modify cancer risk: Smoking, alcohol, multivitamins or minerals, aspirin, dietary fish or taking fish oil.
- Health-related factors: Conditions treated in last month, needing help with daily tasks, activities limited due to health, overall health, number of teeth left, falls in last 12 months, bone fracture in last 5 years, incontinence.

The direct question about outdoor hours asked: 'About how many hours a day would you usually spend outdoors on a weekday and on the weekend?'


53. About how many hours a DAY would you usually spend outdoors on a weekday and on the weekend?

hours per day weekday hours per day weekend

Statistical analysis

The outcome measure was weekly sun exposure hours estimated from responses to the question about number of hours spent outdoors on weekdays and weekend days. Mean ratios (MR) and geometric means (GM) for total hours spent outdoors a week were estimated by fitting sums of squares regression models with log of weekly outdoor hours as outcome, adjusted for age (5 year groups) and sex, using Proc GLM in SAS.

In a first stage, we examined each variable individually, adjusted for age in 5 year age groups and sex only and then entered all variables within each group of related variables in an individual forward stepping model. In a second stage, we derived a final model by entering all variables that were statistically significant within each group in one forward stepping model. A separate process was used to identify the strongest variable among COB, age at arrival and year of arrival for the model fitting: these three related variables were examined together in one model excluding Australian born people. COB was the strongest predictor of skin cancer and was used in these analyses of correlates of sun exposure. Data items or variables of interest as potential correlates of sun exposure were analysed in groups as: personal; lifestyle; sun sensitivity; health. Information on hormonal factors for women was available but is not included in this report.

Total sun exposure

Of the personal, health and lifestyle factors, the independent correlates of sun exposure were:

- being male (more outdoor hours);
- 10 or more times a week of walking or taking moderate activity (more outdoor hours);
- education – a degree meant fewer sun exposure hours and no school certificate or a trade meant more hours;
- residence in a non-metropolitan area in NSW at time of questionnaire response (more outdoor hours);
- the type of housing (more hours for living on a farm),
- the type of work (unpaid work meant more hours);
- reporting excellent health (more outdoor hours);

- having 10 or more alcoholic drinks a week (more outdoor hours); and
- sun sensitivity: outdoors hours increased with increasing tanning ability and decreased with fairer skin colour (Table 1).
-

Table 1. Association of self-reported skin colour with reported hours of sun exposure in people with no history of skin cancer (self-reported).

Skin colour	N	MR (95% CI)*
Males		
Dark	763	1.0
Light olive	6361	0.87 (0.82-0.92)
Fair	11947	0.80 (0.75-0.84)
Very fair	2329	0.66 (0.62-0.70)
		P<0.001
Females		
Dark	572	1.0
Light olive	8743	0.91 (0.84-0.98)
Fair	15164	0.83 (0.77-0.89)
Very fair	3842	0.67 (0.62-0.72)
		P<0.001
Both		
Dark	1335	1.0
Light olive	15104	0.89 (0.85-0.93)
Fair	27111	0.81 (0.77-0.85)
Very fair	6171	0.66 (0.63-0.69)
		P<0.001

* Adjusted for age (5 year groups), and for sex when M & F analysed together

The final set of the strongest correlates (those associated with a 10% or more adjusted increase in MR) for all men and women included male sex, 10 or more times a week of walking or moderate activity, education (as above), housing type (farm meant more hours), overall health, sun sensitivity (each of excellent health and being a good tanner meant more hours). Other variables were included in this final model and were significant, independent correlates of sun exposure hours, but the increase or decrease in MR for any category of any of these variables was less than 10%. These were items such as being in the middle income category (a high income meant fewer hours), older age, doing unpaid work, being a current smoker.

Men and women separately

The main difference between the patterns of correlates when responses for men and women were examined in separate analyses was related to the type of work (Table 2). The MR for sun exposure was increased for men for any work, whether paid or unpaid. Women, however, had fewer sun exposure hours when they reported 25 or more hours of paid work – perhaps an indicator that women in paid employment have busy lives with less time for outdoor activities.

Table 2. Summary of correlates of total sun exposure in men and women separately.

Men	Women
Strong correlates - MR increased by 10+%	
Activity	Activity
Education	Education
Housing- farm	Housing - farm
Tanning	**Skin colour**
Excellent health	Excellent health
<10% increase in MR:	
Non-metro residence	Same as men
Mid-income	Not seen for women
(reduced sun with high income)	(Same as men)
Alcohol - 20+ drinks a week	Any drinks a week
Any paid WORK - increased	**25+ hours paid MR=0.91**
Age retired 55–59 years	n/a
Smoking - current	n/a
No vitamins or minerals	n/a
n/a	Ancestry: southern Europe MR=0.89
n/a	Weight: 90 kg MR=0.94

Weekday and weekend sun exposure

We also examined weekday and weekend hours separately. As might be expected, there were no strong differences between items related to total sun exposure and to weekday sun exposure. Weekend sun exposure, however, was greater in people who had 30 or more hours of paid work – perhaps suggesting that active and busy people continue this lifestyle across all days of the week.

Conclusion

The large number of variables measured in the 45 and Up study have allowed us to identify components of lifestyle and social class that contribute to higher levels of sun exposure. It is clear that sun sensitivity is important: people who are less sun sensitive have more hours in the sun in this population of people who have no history of skin cancer. This is consistent with the possibility that people with sun-sensitive phenotypes adapt their behavior to make greater use of sun protection (Lucas 2010).

Being male, being a reasonably active walker or exerciser, having excellent health and living on a farm all correlate with more hours in the sun, while having a tertiary education at degree level or a high income correlate with fewer hours. Being more active had the strongest correlation with increased sun exposure, supporting an activity-based approach over time-based questions to better measure sun exposure (Yu 2009).

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Vitamin D, past sun exposure & skin phenotype in risk of central nervous system demyelination

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Abstract Latitudinal gradients in multiple sclerosis are well described in both northern and southern hemispheres. Previous studies have suggested that sun exposure and/or vitamin D may provide an explanation for the latitudinal gradient. The Ausimmune Study was a multi-centre case control study specifically designed to address this question. Between 1 November 2003 and 31 December 2006, the study recruited 282 cases, aged 18–59 years, with a first clinical diagnosis of central nervous system demyelination (FCD) from four regions of Australia, spanning latitudes of 27° S to 43° S. Controls were matched on age, sex and study region to cases. Data collected included subjective and objective measures of skin type and past sun exposure and vitamin D status (serum 25-hydroxyvitamin D, 25(OH)D). There was a strong latitudinal gradient in FCD incidence. In case-control analyses higher levels of past sun exposure or 25(OH)D were associated with lower risk of FCD; these factors in combination explained 22% of the observed latitudinal gradient in FCD incidence.

Background

Multiple sclerosis (MS) is a T-cell mediated disease characterised by immune destruction of myelin sheaths in the central nervous system. One of the most striking features of the epidemiology of multiple sclerosis is a latitudinal gradient in occurrence (McLeod et al. 1994). Previous research has suggested that higher levels of sun exposure (van der Mei et al. 2003) and/or vitamin D (Munger et al. 2006) may decrease the risk of multiple sclerosis, with support from both experimental (Cantorna et al. 1996) and epidemiological studies (van der Mei et al. 2001, Munger et al. 2004, 2006). In addition, MS incidence appears to be increasing and the latitude gradient to be decreasing (Ascherio & Munger 2007). If low levels of sun exposure or vitamin D were important for MS onset, increasing incidence would be consistent with lower levels of sun exposure and higher levels of sun protection associated with strong public health programmes for sun protection.

Previous work examining latitudinal gradients (McLeod et al. 1994), or MS risk in relation to sun exposure and/or vitamin D, has used prevalent cases (van der Mei et al. 2001, Kampman et al. 2007), where temporal relationships are not clear and recall bias can impair validity. Two large cohort studies have shown that higher vitamin D intake or serum level (25(OH)D) was associated with decreased MS risk (Munger et al. 2004, 2006), but these studies were unable to concomitantly examine sun exposure or correct for some possible confounders.

In 2003, the Australian Multicentre Study of Environment and Immune Function (the Ausimmune Study) was funded specifically to examine whether there was persistence of a latitudinal incidence gradient in Australia, and then to examine risk in relation to vitamin D and detailed sun exposure measurements.

Methods

Cases: To minimise bias caused by changes in behaviour post-diagnosis, cases (aged 18-–59 years) had an incident first clinical diagnosis of central nervous system demyelination (FCD, often precursor to MS onset) within one of four study regions down the Australian seaboard: Brisbane (27° S); Newcastle and surrounds (33° S), Geelong and the Western Districts of Victoria (37° S) and Tasmania (43° S). We aimed for complete case ascertainment in each study region using a two tier notification system involving neurologists, ophthalmologists, general physicians and radiology practices undertaking relevant MRI scans.

Controls: Each case was matched on age, sex and study region to between 1 and 4 controls randomly selected from the Australian Electoral Roll.

Data: Participants completed questionnaires providing data on ancestry, date of arrival in Australia, self-reported sun exposure at different ages in summer and in winter during weekends and holidays (leisure), propensity to burn or tan, use of sun protection, smoking history, exposure to chemicals, skin cancer history and use of vitamin D containing supplements. Each participant also completed a food frequency questionnaire and a calendar recording location of residence and usual leisure sun exposure in summer and winter for every year of life.

Local research officers (LROs) undertook a physical examination, noting eye and natural hair colour, height and weight and presence of solar keratoses and naevi. Skin melanin density was derived from reflectance spectrophotometer readings at 400 nm and 420 nm for sun exposed (hand, left back shoulder) and unexposed (buttock and upper inner arm) skin, as previously described (Dwyer et al. 2002). LROs made silicone rubber casts of the dorsum of both hands and these were graded using digital photography on a scale of 1 (no sun damage) to 6 (marked sun damage) (Lucas et al. 2009). We have previously shown that the cast score correlates well with cumulative sun exposure over the lifetime (Lucas et al. 2009).

Blood was separated and stored at -80 °C until study completion. 25(OH)D level was measured by liquid chromatography dual mass spectrometry and DNA was typed for vitamin D binding protein alleles previously noted to alter 25(OH)D levels (Sinotte et al. 2009).

Results

Ninety-one percent (n=282) of eligible FCD cases and 60% (n=558) of contacted controls consented to participate in the Ausimmune Study. There was a strong latitudinal incidence gradient increasing from 2.83 per 100,000 in Brisbane (27° S) to 9.90 per 100,000 in Tasmania (43° S), a 3.5 fold increase or 9% per higher degree of latitude (Figure 1).

Higher past, recent or cumulative self-reported sun exposure were associated with reduced FCD risk, e.g., leisure time sun exposure (age 6 y to current) Adjusted

Odds Ratio (AOR)=0.69 (95%CI 0.55–0.86) per 1000KJ/m^2 increase in ultraviolet radiation (UVR) dose, with a stronger effect for recent than for early life, sun exposure. Sun-related skin damage as assessed by silicone skin cast score was also associated with decreased risk: AOR=0.43 (95%CI 0.21–0.88) for the highest grade (6), compared to the lowest (2) (Figure 2). There was an 8% decrease in the odds of being a case per 10 nmol/L increase in serum 25(OH)D level (AOR=0.92 (95%CI 0.86–0.98)) and a 34% decrease per 50 nmol/L increase (AOR=0.66, 95%CI 0.48–0.91). Further adjustment for skin type and other phenotypic factors did not alter the association. Measures of high dose, intermittent sun exposure, e.g., past history of blistering sunburn, were associated with an increased risk of FCD, AOR=1.33 (95%CI 0.93–1.89).

There was some evidence that cases were more likely to start a vitamin D supplement post-diagnosis, but exclusion of those participants who started a supplement after the date of the cases' first episode did not change the findings. There was a gradient of increasing skin fairness with increasing latitude. Differences in skin type, cumulative UVR dose and serum 25(OH)D level accounted for 22% of the higher FCD incidence in the 43°S vs. the 27°S regions.

Conclusion

There is a strong latitudinal gradient in occurrence of a first diagnosis of CNS demyelination in Australia, with some diminution of that reported for prevalent MS in 1994. Lower sun exposure or vitamin D status are associated with increased odds of a FCD. The effects persist after adjustment for skin phenotype and known risk factors for MS. Recent sun exposure appeared to be more important than early-life sun exposure. There was no evidence of a threshold of effect for 25(OH)D level, but rather a continuous decrease in risk across the range of values. Cumulative sun exposure, skin type and 25(OH)D level accounted for only part of the latitudinal FCD incidence gradient in Australia.

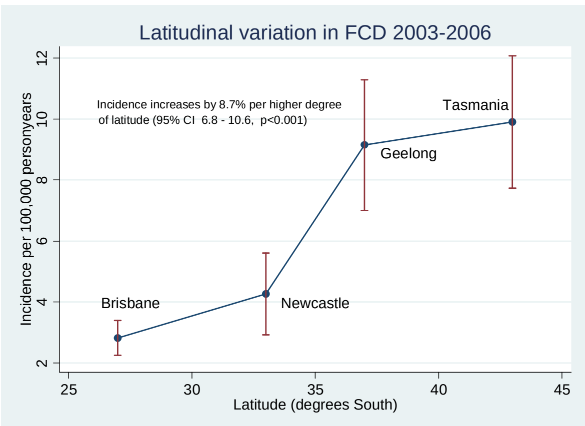

Figure 1. Latitudinal variation in FCD incidence in Australia 2003-2006.

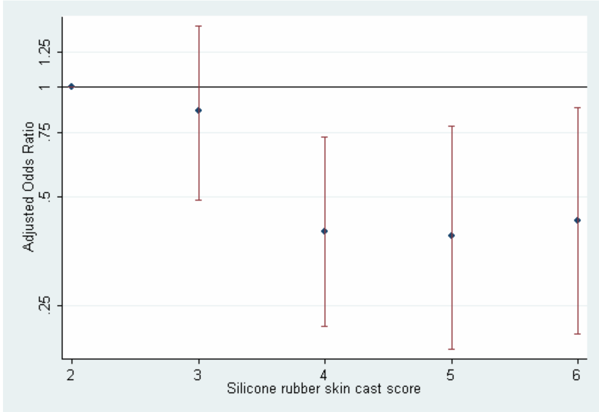

Figure 2. Adjusted odds ratio for FCD status according to skin cast score.

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Vitamin D3, the skin immune system and cutaneous carcinogenesis

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Abstract. UVB-induced DNA damage and suppression of the skin immune system (SIS) are major aetiological agents in the development of skin cancer. UVB irradiation of the skin also causes the production of vitamin D3. Evidence suggests that local conversion of vitamin D3 to its biologically active form may be important in protecting against UVB-induced immunosuppression of the SIS. The aim of this study was to determine if dietary vitamin D3 protects against UVB-induced immunosuppression of the contact hypersensitivity (CHS) response. To assess this an *in vivo* study of UVB-induced suppression of the CHS response in vitamin D3 replete and deficient BALB/c and C57BL/6 mice was undertaken. The level of UVB-induced immunosuppression was significantly higher in vitamin D3 deficient C57BL/6 male and female mice when compared to their vitamin D3 replete counterparts. Vitamin D3 deficiency did not alter the level of UVB-induced immunosuppression in BALB/c mice. The protection against UVB-induced immunosuppression may relate to differences in levels of UVB-induced DNA damage (thymine dimers) of cells of the skin and UVB-induced production of vitamin D3.

Vitamin D3 and skin cancer development

Skin cancer is the most common cancer in the world. The majority of skin cancers are caused by exposure of the skin to ultraviolet B radiation (UVB). UVB irradiation causes DNA damage to cells of the skin and suppression of the SIS. However, UVB irradiation also causes the production of vitamin D3 by keratinocytes that also undergoes sequential enzymatic hydroxylation to become the biologically active form, 1α,25 dihydroxyvitamin D3 (1α,25(OH)$_2$D3) within the skin. Recently an increase in the levels of 1α,25(OH)$_2$D3 in mouse skin following UVB-irradiation has been demonstrated (Biggs et al. 2010).

Topically applied 1α,25(OH)$_2$D3 to skin can suppress the SIS but can also protect skin against UVB-induced DNA damage (thymine dimers) and UVB-induced immunosuppression (reviewed by Kuritzky et al. 2008).The protection against UVB-induced immunosuppression may contribute to a reduced risk of skin cancer development. The focus of this study was to determine whether dietary vitamin D3 similarly influenced the skin's response to UVB irradiation.

Materials and methods

An *in vivo* study of UVB-induced suppression of the contact hypersensitivity (CHS) response in vitamin D3 replete and deficient BALB/c and C57BL/6 mice was undertaken. Mice were protected from UVB exposure and started on a vitamin D3 deficient diet at three weeks of age. Breeding pairs of vitamin D3 replete and vitamin D3 deficient mice were formed and the offspring of these mice were used in experiments. Mice were irradiated with a bank of six FS40 sunlamps, in perspex cages, covered with clear polyvinylchloride plastic to exclude wavelengths less than 290 nm. The dorsal skin was shaved prior to UVB irradiation and the ears protected by sunscreen (5% 2-ethylhexyl-p-methoxycinnimate). To suppress the SIS, mice were exposed to UVB irradiation ((1,1,1,2,2,2 kJ/m^2) and (1,1,1,2,2 kJ/m^2)) in BALB/c and C57BL/6 mice respectively) on consecutive days and compared to similarly treated but sham irradiated mice. Lateral tail vein blood samples were taken for quantification of 25(OH)D3 prior to and 48 hours after the last UVB irradiation. Mice were sensitised with the contact sensitiser oxazolone through UVB or sham irradiated skin, 72 hours after the last UVB irradiation. Ears were challenged 7 days post sensitisation, ear swelling measured 24 hours later, and the percent suppression of the CHS response calculated by comparing the CHS response of sham irradiated mice to UVB irradiated mice. To assess UVB induced DNA damage the dorsal skin from mice was taken following UVB irradiation and the epidermal keratinocytes analysed for the presence of thymine dimers (TD) using immunohistochemistry.

Results

The level of UVB-induced immunosuppression was significantly higher in vitamin D3 deficient C57BL/6 male and female mice when compared to their vitamin D3 replete counterparts. In contrast, vitamin D3 replete and deficient BALB/c mice showed similar levels of UVB-induced immunosuppression. Thus, dietary vitamin D3 protects against UVB-induced immunosuppression of the CHS response in C57BL/6 but not BALB/c mice.

UVB-induced DNA damage is required for UVB-induced suppression of the SIS in mice (Applegate et al. 1989). Therefore, the inability of vitamin D3 to protect against UVB-induced immunosuppression in BALB/c mice compared to C57BL/6 mice may reflect differences in the capacity of vitamin D3 to reduce UVB-induced DNA damage and promote DNA repair. Vitamin D3 did not lower the initial UVB-induced mean percentage of TD positive keratinocyte nuclei in male or female C57BL/6 mice. However, vitamin D3 did lower the intensity of TD staining, a factor that reflects the lower numbers of TD within the nucleus, in both male and female C57BL/6 mice. Conversely, vitamin D3 did not significantly influence either the percentage of TD positive nuclei or level of TD staining in BALB/c male or female mice.

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Promotion of UVB-induced DNA repair is also associated with reduced UVB-induced immunosuppression (Applegate et al. 1989). The rate of disappearance of TD positive nuclei was estimated as an indicator of whether vitamin D3 influenced DNA repair. Vitamin D3 significantly reduced the percentage of keratinocyte nuclei containing TD in C57BL/6 male mice, and a trend for reduction was identified in C57BL/6 female mice, 48 hours after UVB irradiation. Conversely, vitamin D3 did not alter the reduction in TD nuclei over a 72 hour period in BALB/c mice,

UVB irradiation caused a significant elevation in serum 25(OH)D3 levels in both BALB/c and C57BL/6 vitamin D3 deficient mice. Despite receiving one less UVB irradiation the C57BL/6 mice had similar 25(OH)D3 levels to their BALB/c counterparts. The elevation in 25(OH)D3 was significantly higher in female mice than male mice for both strains.

Discussion

The availability of 25(OH)D3 protected against UVB-induced immunosuppression of the CHS response in the C57BL/6 but not BALB/c mice. Vitamin D3 did not lower the initial UVB-induced mean percentage of TD positive keratinocyte nuclei in male or female C57BL/6 mice. However, vitamin D3 did lower the intensity of TD staining, a factor that reflects the lower numbers of TD within the nucleus, in both male and female C57BL/6 mice. This suggests that vitamin D3 subtly reduces the level of TD in C57BL/6 mice and thus may contribute to protection against UVB-induced immunosuppression in these mice. Conversely, vitamin D3 did not significantly influence either the percentage of TD positive nuclei or level of TD staining in BALB/c male or female mice and did not protect against UVB-induced immunosuppression. These findings suggest that vitamin D3 photoprotection against UVB-induced DNA damage in C57BL/6 mice may account for the reduced UVB-induced immunosuppression in vitamin D3 replete C57BL/6 mice. Consequently, vitamin D3 protection against UVB-induced DNA damage may be dependent on the genetic background of the mice.

This suggests that vitamin D3 also promotes the repair of TD, which may lead to reduced UVB-induced immunosuppression in C57BL/6 mice. Conversely, vitamin D3 did not alter the reduction in TD nuclei over a 72 hour period in BALB/c mice, or reduce UVB-induced immunosuppression in BALB/c mice. These results indicate that photoprotection by vitamin D3 in C57BL/6 mice is related to reduced UVB-induced DNA damage and potentially enhanced repair. These results also suggest that genetic differences influencing the susceptibility to UVB-induced immunosuppression may relate to DNA repair mechanisms. A compromise in the repair of UVB-induced TDs in neonatal $VDR^{-/-}$ mice has also been demonstrated (Ellison et al. 2008).

Kuritzky et al. (2008) suggested that $1\alpha,25(OH)_2D3$ produced from one UVB exposure is unlikely to exert photoprotective effects in the skin, as the production of $1\alpha,25(OH)_2D3$ in the UVB irradiated epidermis takes several hours, but photoprotection could occur after subsequent UVB exposures. Therefore, as vitamin D3 contributed to a potential improvement in DNA repair in C57BL/6 mice, the repeated UVB irradiation used to induce local immunosuppression may have resulted in cumulatively less DNA damage in C57BL/6 mice. Less DNA damage would also contribute to the protection against UVB-induced immunosuppression conferred by vitamin D3 in C57BL/6 mice.

The levels of $1\alpha,25(OH)_2D3$ achieved in the skin following UVB irradiation may also influence the rate of DNA repair. Skin production of vitamin D3 in BALB/c and C57BL/6 mice may be inferred from the rise in the serum 25(OH)D3 levels following UVB irradiation. C57BL/6 mice had similar rises in 25(OH)D3 as BALB/c mice after UVB-irradiation, even though they received one less 2 kJ/m^2 dose of UVB-irradiation. This could indicate that C57BL/6 mice produce more vitamin D3 and $1\alpha,25(OH)_2D3$ locally in the skin. If the rise in serum 25(OH)D3 levels in C57BL/6 mice does reflect higher levels of UVB-induced $1\alpha,25(OH)_2D3$ within the skin, compared to BALB/c mice, this may contribute to the increased sensitivity of C57BL/6 mice to UVB-induced immunosuppression when compared to BALB/c mice. However, greater local production of $1\alpha,25(OH)_2D3$ may contribute to the enhanced DNA repair in C57BL/6 mice.

The extent of UVB-induced immunosuppression will depend on the balance between $1\alpha,25(OH)_2D3$ mediated photoprotection against DNA damage and the promotion of DNA repair (and therefore a reduction in UVB-induced immunosuppression) and the inherent ability of locally produced $1\alpha,25(OH)_2D3$ to suppress the SIS.

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Considerations for increasing vitamin D in the food supply

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Abstract. The New Zealand Food Safety Authority (NZFSA) has identified vitamin D as an emerging nutrition issue. In New Zealand, voluntary fortification of certain foods with vitamin D is currently permitted. Food Standards Australia New Zealand requires accurate nutrient data to conduct quality risk assessments for voluntary or mandatory fortification of the food supply. Committed to a science and risk-based approach, NZFSA has commissioned a review of the vitamin D data in the New Zealand Food Composition Database.

Background

The New Zealand Food Safety Authority (NZFSA) is committed to providing a science and risk-based approach to nutrition issues within its wider role of improving the safety and suitability of the food supply (New Zealand Food Safety Authority 2009). Vitamin D was identified as an emerging nutrition issue following an increase in scientific evidence on vitamin D and its impact on health. In 2005, NZFSA and the Ministry of Health commissioned a literature review to summarise the evidence on vitamin D, including its impact on health, and an overview of international strategies and contextualise this to the New Zealand situation (Rockell et al. 2008).

Importance of vitamin D

Vitamin D is an essential nutrient that can be synthesised in the body through exposure to sunlight or obtained through eating foods that are sources of vitamin D (Mann & Truswell 2002). It plays a significant role in bone health, and deficiency can lead to rickets in children and osteomalacia and osteoporosis in adults (National Health and Medical Research Council 2005). Results from most recent National Adults' and Childrens' Nutrition Surveys indicate a prevalence of vitamin D deficiency in three and four percent of New Zealand adults and children respectively (Rockell et al. 2005, 2006).

Sources of vitamin D

Vitamin D can be synthesised in the body through sun exposure of the skin. For most free-living people, vitamin D through sun exposure is the largest contributor to vitamin D status (Holick 2004).

Vitamin D is naturally present in a few foods such as oily fish (e.g. salmon and sardines) and eggs (Mann & Truswell 2002). Vitamin D-fortified foods and dietary supplements may be beneficial for those population groups that are at high risk of deficiency, have limited sun exposure and consume few naturally containing food sources of vitamin D (Rockell et al. 2008).

Existing food regulations and standards

The Australia New Zealand Food Standards Code regulates the addition of vitamins and minerals to food. In New Zealand, vitamin D (as either ergocalciferol or cholecalciferol) is permitted to be added to a wide range of foods including margarine, milk, yoghurt, dairy desserts and certain formulated supplemented foods. In addition to these permissions, fortification of margarine and edible oil table spreads is a mandatory requirement in Australia. (Food Standards Australia New Zealand 2002).

The New Zealand Supplemented Food Standard, which came into effect in March 2010, regulates food-type dietary supplements that were previously covered under the Dietary Supplement Regulations 1985. Food-type dietary supplements are permitted to contain a maximum of 40 µg (1600 IU) vitamin D per one day quantity. This is 15 µg (600 IU) more than permitted for dietary supplements which are still covered under the Dietary Supplement Regulations 1985. (New Zealand Food Safety Authority) (New Zealand Government 1985)

New Zealand trends in vitamin D fortification

The number of foods fortified with vitamin D in New Zealand has increased since 1999 (Figure 1).

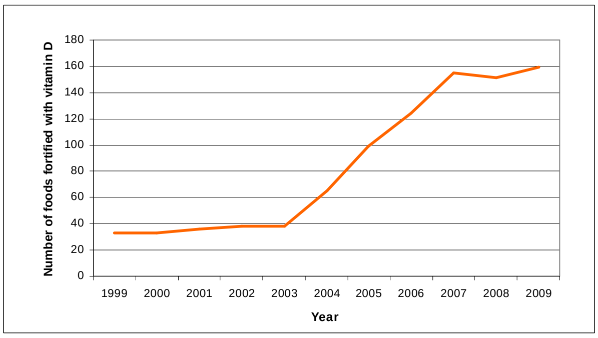

Figure 1. Total number of foods fortified with vitamin D between 1999 and 2009 in the Manufactured Food Database.

The Manufactured Food Database[1] (MFD) report that between 2004 and 2009 the number of yoghurts fortified with vitamin D increased from 1 to 53; skim milk and reduced fat milks increased from 17 to 32; and dairy desserts from zero to 25 (Figure 2) (Alannah Steeper, MFD, pers. comm. February 2010).

Despite a notable increase in yoghurts fortified with vitamin D in the MFD in 2009, this represents only 31 percent (53 out of 171) of all yoghurts reported. In contrast, 83 percent (25 out of 30) of all dairy desserts were fortified with vitamin D in 2009. (Alannah Steeper, pers. comm, February 2010).

[1] The Manufactured Food Database collates data supplied voluntarily by food manufacturers and may not represent all manufactured food currently fortified in New Zealand.

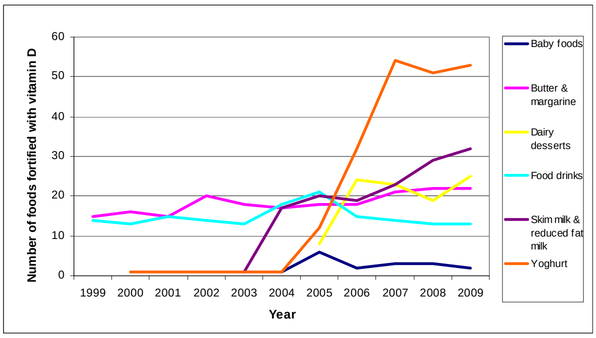

Figure 2. Trends in the type of foods fortified with vitamin D from 1999 to 2009 in the Manufactured Food Database.

Considerations in fortifying food with vitamin D in New Zealand

Fortification of the food supply, whether mandatory or voluntary, requires consideration of a number of issues. The Policy Guideline for the Fortification of Vitamins and Minerals outlines specific principles for voluntary and mandatory fortification of which Food Standards Australia New Zealand (FSANZ) must have regard in developing or reviewing regulatory measures. For example, if an increase in voluntary permissions for vitamin D is sought, there must be evidence of deficiency of vitamin D in the population or evidence of the likelihood of deficiency from changes in food habits. (Australia New Zealand Food Regulation Ministerial Council 2006).

In conducting its risk assessment, FSANZ will assess exposure to vitamin D from dietary sources (food and dietary supplements) and vitamin D synthesised from exposure to sunlight. An assessment of dietary exposure will consider possible food vehicles for fortification (e.g., margarine or milk) and the concentrations of vitamin D to be added. Population estimates of vitamin D intake can then be calculated using National Nutrition Survey data and assessed against documented nutrient reference values. Concentrations of vitamin D provided in national food composition databases must be representative and of sound analytical quality to obtain an accurate population estimate of vitamin D intake.

Next steps

In March 2010, NZFSA commissioned a review of the vitamin D data in the New Zealand Food Composition Database (NZFCD) with the aim of improving the utility of this data. The New Zealand Food Safety Authority is interested in finding out whether the data are accurate and representative of vitamin D-containing foods, what gaps exist in the current data, assessing the sensitivity and specificity of methods of analysis and technological issues associated with vitamin D fortification. Depending on the outcome of the review, it is anticipated that a plan will be developed to update vitamin D data in the NZFCD in the future.

Acknowledgment Alannah Steeper, Manufactured Food Database, Nutrition Services, Auckland City Hospital.

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Vitamin D and cardiovascular disease: are we at a tipping point?

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Abstract. Cardiovascular disease mortality is associated temporally and geographically with low UV radiation, being increased in winter and in populations living at high latitudes, and decreased in populations living at high altitudes. UVB radiation is the primary source of vitamin D in humans, and several recent cohort studies have shown the low vitamin D levels at baseline predict increased risk of cardiovascular disease. However, randomised controlled trials of vitamin D supplementation are urgently required to provide certainty as to whether vitamin D protects against cardiovascular disease.

Background

Up until the 1970s, it was generally held by researchers active in the area that vitamin D was a cause of cardiovascular disease. This view point arose from animal studies showing that pharmacological doses of vitamin D (up to 5–10 000 IU per kg) resulted in arteriosclerosis. This was challenged in the 1970s by small case control studies, using the newly developed methods to measure 25-hydroxyvitamin D (25(OH)D), the main marker of vitamin D status. Contrary to expectations, these studies, including a case control study nested within a cohort from Tromsø, Norway (Vik et al. 1979), found that myocardial infarction cases had 25(OH)D levels similar to or lower than controls (Table 1).

A review of the descriptive epidemiology of cardiovascular disease, which has increased mortality in winter and at high latitudes, along with decreased mortality at high altitudes, led to the idea that UV radiation, by increasing vitamin D levels, may protect against cardiovascular disease (Scragg 1981). This hypothesis was tested in a case control study carried out in Auckland in the 1980s which observed a significant inverse association between plasma levels of 25(OH)D and risk of myocardial infarction (Scragg et al. 1990).

However, aside from a couple of small case control studies, no major epidemiological studies on vitamin D and cardiovascular disease were published until 2008. Since then, several cohort studies from community-based samples have been published, all showing inverse associations between baseline 25(OH)D levels and subsequent risk of cardiovascular disease. These studies, which provide the best quality evidence on causation, aside from intervention studies, are reviewed below.

Cohort studies

The first published cohort study came from the offspring of the original participants in the well known Framingham study which in the 1950–60s identified the major risk factors for cardiovascular disease. The recent Framingham Study Offspring Cohort followed 1739 men and women (mean age 59 years) (Wang et al. 2008).

Table 1. Summary of community-based cohort studies of blood levels of 25-hydroxyvitamin D and cardiovascular disease.

Vik (1979), Tromso, Norway.
- Nested case control study. Data from 23 cases and 46 matched controls free of disease at baseline.
- 25(OH)D (Mean ±SD) in cases (59.0 ±24.1 nmol/L) was similar to controls (63.4 ±27.2); but lower in cases after correcting for blood level of vitamin D binding protein (p=0.024).

Wang (2008), Framingham, USA.
- Outcome: cardiovascular disease (fatal & non-fatal)
- Adjusted hazard ratio (95% CI) by category of 25(OH)D:
    - ≥15 ng/mL = 1.00
    - 10 to <15 ng/mL = 1.53 (1.00, 2.36)
    - <10 ng/mL = 1.80 (1.05, 3.08)

  p-value for linear trend = 0.01

Giovannucci (2008), male health professionals, USA.
- Outcome: coronary heart disease (fatal & non-fatal)
- Adjusted odds ratio (95% CI) by category of 25(OH)D:
    - ≥30 ng/mL = 1.00
    - 22.6-29.9 ng/mL = 1.60 (1.10, 2.32)
    - 15.1-22.5 ng/mL = 1.43 (0.96, 2.13)
    - ≤15.0 ng/mL = 2.09 (1.24, 3.54).

  p-value for linear trend = 0.02

Ginde (2009), US representative sample (NHANES).
- Outcome: cardiovascular disease (fatal only)
- Adjusted hazard ratio (95% CI) by category of 25(OH)D:
    - <25.0 nmol/L = 1.83 (1.14, 2.94)
    - 25.0-49.9 nmol/L = 1.47 (1.09, 1.97)
    - 50.0-74.9 nmol/L = 1.21 (0.92, 1.59)
    - 75.0-99.9 nmol/L = 1.15 (0.86, 1.53)
    - ≥100.0 nmol/L = 1.00

Kilkkinen (2009), Mini-Finland Health Survey, Finland.
- Outcome: cardiovascular disease (fatal only)
- Adjusted hazard ratio (95% CI) by quintile of 25(OH)D:
    - Quintile 1 (low) = 1.00
    - Quintile 2 = 1.04 (0.86, 1.26)
    - Quintile 3= 0.81 (0.66, 1.00)
    - Quintile 4 = 0.86 (0.70, 1.06)
    - Quintile 5 (high) = 0.76 (0.61, 0.95)

  p-value for linear trend = 0.005

Pilz (2009), Hoorn Study, Holland
- Outcome: cardiovascular disease (fatal only)
- Adjusted hazard ratio (95% CI) by quartile of 25(OH)D:
    - Upper 3 quartiles = 1.00
    - First quartile (low) = 5.02 (1.88, 13.42)

Semba (2010), InCHIANTI Study, Italy.
- Outcome: cardiovascular disease (fatal only)
- Adjusted hazard ratio (95% CI) by quartile of 25(OH)D:
    - <10.5 ng/mL = 2.57 (1.12, 5.91)
    - 10.5-16.0 ng/mL = 1.76 (0.80, 3.89)
    - 16.1-25.6 ng/mL = 2.28 (1.09, 4.79)
    - >25.6 ng/mL = 1.00

Table 1 shows increased hazard ratios of dying from cardiovascular disease during the 5-year follow-up period in the Framingham Offspring study, compared to the reference group (baseline 25(OH)D ≥15 ng/ml), adjusted for demographic variables, blood pressure, blood lipids, cigarette smoking and body mass index.

The second publication was a nested case control study, from within a cohort study of 18 225 US male health professionals aged 40–75 years followed for 10 years (Giovannucci et al. 2008). This study found a significant inverse association (p=0.02) between baseline plasma 25(OH)D and risk of coronary heart disease, adjusted for demographic and cardiovascular variables including month of blood collection, history of hypertension and diabetes, blood lipids, smoking status, alcohol intake, physical activity and body mass index (Table 1).

The third study was from the Third National Health and Nutrition Examination Survey (NHANES), a random sample of the US civilian population, which was originally surveyed in 1988–94 and followed-up for mortality until 2000 (Ginde et al. 2009). A significant inverse association was found between baseline 25(OH)D level and risk of cardiovascular death during follow-up in participants aged 65 years and over at baseline, adjusted for demographic and cardiovascular variables including season of blood collection, BMI, physical activity, smoking, blood pressure and blood lipids (Table 1).

The fourth study was the Mini-Finland Health Survey, which in 1978–80 interviewed 6219 Finns selected randomly from a population register, and followed them up to 2006 (Kilkkinen et al. 2009). Risk of cardiovascular death decreased significantly with increasing baseline 25(OH)D (p=0.005), adjusted for demographic and a wide range of cardiovascular variables including season, BMI, smoking, leisure-time physical activity and alcohol intake (Table 1).

The fifth cohort study to publish results was the Hoorn Study from Holland, which interviewed 614 participants, recruited from a municipal register, in 2000–01 (mean age 70 years) and followed them until July 2007 (Pilz et al. 2009). Participants in the lowest quartile of baseline 25(OH)D had a 5-fold increased risk of dying from cardiovascular disease, compared to those in the other three quartiles, adjusting for demographic variables and a wide range of cardiovascular variables including smoking, physical activity, waist-to-hip ratio, blood pressure, HDL-cholesterol, and kidney function (Table 1).

The sixth study comes from the InCHIANTI study, Italy, which examined 1006 people aged 65 years and over recruited from a population register in 1998–99 and followed for 6.5 years (Semba et al. 2010). This study found that people with baseline 25(OH)D levels in the lowest quartile had an approximate 2.5 fold increased risk of dying from cardiovascular disease compared with those in the highest quartile (Table 1).

Conclusion

All cohort studies of community selected samples have reported significant inverse associations between baseline blood vitamin D levels and risk of developing or dying from cardiovascular disease during the follow-up period (Table 1). Collectively, these are very compelling results which suggest that vitamin D may reduce the risk of developing cardiovascular disease. However, over the last 10–15 years there have been several examples of exposure-disease associations observed in cohort studies which have not been confirmed by clinical trials. These include hormone replacement therapy and cardiovascular disease, beta-carotene and cancer, and vitamin E and cardiovascular disease.

We are indeed at a tipping point with regard to vitamin D and cardiovascular disease. While cohort studies provide strong evidence to support a causal association between low vitamin D status and increased risk of cardiovascular disease, certainty about the association will only come from large randomised clinical trials designed to determine if vitamin D supplementation reduces the risk of cardiovascular disease. There is an urgent public health need to do such studies, as vitamin D is very cheap (a year's supply costs about $5) and could be given at low cost to large sections of the population if it is shown to be beneficial.

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Factors associated with body coverage and personal UV radiation dose: preliminary findings

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Abstract. Personal received solar ultraviolet radiation (UVR) is the primary influence on serum 25-hydroxyvitamin D (25(OH)D) levels. Demographic, personal and behavioural factors have the potential to affect received UVR. Body clothing coverage and personal dosimeter UVR data from 247 participants (18–80 years) in Year 1 of the Vitamin D and Sun Exposure study were analysed and associations with demographic, personal and behavioural factors investigated.

Introduction

Levels of 25(OH)D among many in the New Zealand population have been reported as insufficient. Received solar ultraviolet radiation (UVR) is the primary influence on serum 25(OH)D levels. However, little is known about the relations between UVR exposure and vitamin D levels. Accordingly, one aim of the overall project, of which this study is part, was 'to quantify relations between sun exposure and changes in controlling for demographic, personal and geophysical factors.' These factors include sex, age, self-defined ethnicity, skin type, Body Mass Index (BMI)), outdoor occupation, geographical region, season and weekend versus weekday exposure. The present study focuses on the associations between UVR and body coverage and these possible influences. Information about potentially modifiable factors is important for the design of health promotion interventions for reducing the risk of vitamin D deficiency or insufficiency as well as skin cancer. Similarly, information about non-modifiable factors is potentially useful for targeting health promotion interventions. The specific aims for the study reported here were to report differences in percentage body coverage and personal UVR dose, in SEDs, by key demographic and personal factors.

Methods

Study sample

The sample for these preliminary analyses included all those recruited during Year 1 (2008) of the overall study for whom full data were available *(*Table 1*)*.

Table 1. Participants included in statistical models.

	Auckland	Dunedin	Total
Females	117	51	168
Males	44	35	79
	161	86	247

Instruments

UVR exposure was measured by personal dosimeter fixed onto an elastic armband with a velcro closure worn outside clothing. These dosimeters have a spectral response that closely matches the erythemal action spectrum and provide time-stamped measures of UVR thereby, for example, allowing comparison between weekday and weekend exposure. Their full technical specifications were described elsewhere (Allen et al. 2005), and their use has been reported in two population studies, one among schoolchildren, (Wright et al. 2007) the other among outdoor workers (Hammond et al. 2009). The daily diary used to obtain data on body coverage was based on a clothing diary previously developed and used among schoolchildren (Wright et al. 2007), then adapted for use in the study of outdoor workers (Hammond et al. 2009) and finally extended for the current study to include a wider range of adult clothing, allowing for cultural differences. The diary time periods were the three time bands used for southern hemisphere sun protection advice, September to March, before 11 am, 11 am to 4 pm, and after 4 pm. This report focuses on the middle period, during which about 64% of total UVR dose was received. The clothing data were then converted to percentage body coverage using the Lund and Browder chart (Hettiartchy & Papini 2004). Height and weight were measured using, respectively, a SECA stadiometer and Tanita HD-316 scales by Wedderburn. From these two measures, a body mass index (BMI) value (kg/m^2) was calculated. Skin colour at the upper inner arm, an area minimally exposed to the sun, was measured using a Datacolor CHECK™ spectrophotometer and converted to individual typology angle (ITA) values, following Del Bino et al. (2006). Outdoor occupation was based on self reports of the past four weeks obtained during baseline interview.

Results

The distribution of arithmetic mean percentage body coverage by calendar month for the Auckland and Dunedin participants is presented, with 95% confidence intervals in Figure 1. There were consistently higher levels of body coverage for the more southerly, Dunedin participants. There was a divergence in mean body coverage between the two centres in spring (after August), with Dunedin coverage remaining relatively steady, but Auckland coverage gradually reducing. The highest levels of mean body coverage, mostly above 80%, occurred approximately from April to September, usually the coldest months in both centres.

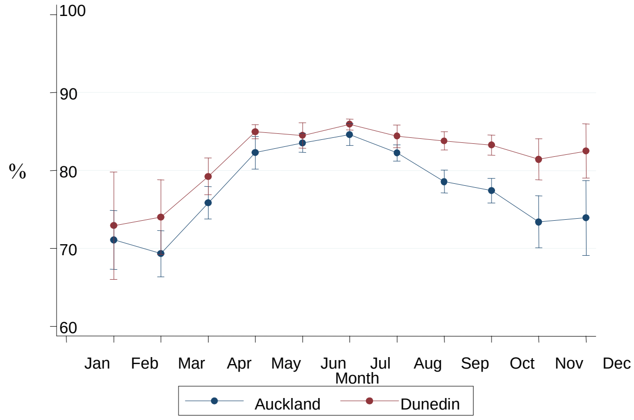

Figure 1. Arithmetic mean percentage body overage.

The associations of a range of plausible influences with reported body coverage and dosimeter measured SEDs are presented in Tables 2 and 3, respectively. Each partially adjusted model controls for centre, season and the interaction between these two factors, whereas the fully adjusted models control for all reported factors. Fractional polynomials were used to assess the linearity of the continuous predictors (age, BMI, and ITA), but no significant departures from linearity were noted. With respect to body coverage (Table 1), an age effect in the partially adjusted model remains statistically significant when fully adjusted for all factors, with increased coverage for increasing age. A weekend effect is the only other effect that is statistically significant in both models, with lower coverage at weekends. The outdoor worker effect goes from being marginally statistically significant in the partially adjusted model (lower coverage for outdoor workers) to a non-statistically significant result in the fully adjusted model. When log-transformed SEDs and cloud adjusted maximum UVR were individually added to the model, higher SEDs and higher maximum UVR were each statistically significantly associated with lower body coverage ($p<0.001$ for both).

Table 2. Body coverage models.

	Partially adjusted model		Fully adjusted model	
	Difference in arithmetic means (95% CI)	p-value	Difference in arithmetic means (95% CI)	p-value
ITA, per 10 units)	-0.1 (-0.5-0.3)	0.575	-0.2 (-0.5-0.2)	0.404
Female	1.1 (-0.5-2.8)	0.177	0.9 (-0.6-2.4)	0.233
BMI (per 5 units)	-0.3 (-0.9-0.2)	0.261	-0.3 (-0.8-0.2)	0.279
Age (per 10 yrs)	0.7 (0.3-1.1)	0.001	0.7 (0.3-1.1)	0.002
Weekend	-2.7 (-3.3--2.1)	<0.001	-2.7 (-3.3—2.1)	<0.001
Outdoor worker	-2.6 (-5.1-0.0)	0.046	-1.9 (-4.4-0.6)	0.131

For dosimeter measured SEDs, there was a non-statistically significant tendency for females to have a lower SEDs dose in the partially adjusted, but not the fully adjusted, model. For each decade of age, the dose increased by roughly a quarter in both models. There was a significantly lower dose at weekends in both models. An outdoor worker effect was statistically significant in both models, with an approximate doubling of dose in the fully adjusted model. When cloud adjusted maximum UVR was added to the model, it was statistically significantly associated with higher SEDs ($p<0.001$), while the other associations remained unchanged.

Table 3. UVR dose models.

	Partially adjusted model		Fully adjusted model	
	Difference in arithmetic means (95% CI)	p-value	Difference in arithmetic means (95% CI)	p-value
ITA, per 10 units)	1.04 (0.95-1.12)	0.431	1.06 (0.97-1.15)	0.186
Female	0.74 (0.53-1.02)	0.068	0.82 (0.59-1.13)	0.215
BMI (per 5 units)	1.04 (0.91-1.19)	0.537	1.00 (0.88-1.14)	0.988
Age (per 10 years)	1.23 (1.11-1.37)	<0.001	1.26 (1.13-1.39)	<0.001
Weekend	0.80 (0.69-0.93)	0.004	0.8 (0.69-0.93)	0.004
Outdoor worker	1.79 (1.17-2.73)	0.008	1.95 (1.24-3.07)	0.004

Discussion

A number of plausible, statistically significant results were obtained and these potentially have considerable practical significance. Those who reported occupational outdoor work were found to have almost double the UVR dose. Body coverage increased significantly with increasing age, whereas UVR dose increased by approximately 25% for each decade of age. There was lower body coverage at weekends, but also a lower UVR dose. The latter may be due to spending time indoors, but could also indicate lower compliance with study protocols on wearing dosimeters at weekends. Some next steps will be to confirm these preliminary findings in the full dataset and to identify and investigate plausible interactions.

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Vitamin D and its association with personal UV exposure

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Abstract. In this study we relate levels of vitamin D with personal UV exposures in two centres from measurements taken over an 8 week period for each participant. The results presented here are an assessment of analytical methods and a demonstration of these methods using preliminary partial data. Depending on assumptions the dose response measure differs so we must be clear what relationship we are interest in and which analytical model gives this estimate.

Introduction

Low levels of vitamin D have been implicated in a wide variety of health issues, including rickets, osteomalacia, osteoarthritis, many forms of cancer (e.g.,. colon, breast), multiple sclerosis, diabetes, hypertension, coronary heart disease and reduced lung function. New Zealanders have low vitamin D levels compared to other developed countries, with the mean level in adult New Zealanders being 50 nmol/L (Rockell et al. 2006). A significant proportion have suboptimal levels of vitamin D, particularly Pacific, Maori, and South Asian people.

The primary source of vitamin D is sun exposure; and the amount of vitamin D produced from sun exposure varies with age, skin pigmentation, time of year and day, and latitude. However, there is limited information on how much sun exposure is needed to maintain vitamin D at the optimum levels required for good health. The time required outdoor in the sun to receive 1/6 to 1/3 of one MED, in order to produce between 1500 and 3750 IU of vitamin D, has been estimated for people with white (Fitzpatrick type II) skin living in the main Australian cities (Samenek et al. 2006). There is no indication from this study of the serum $25OHD_3$ levels that would be achieved by the above sun exposures in people with varying skin colours.

The aim of the current study is to determine the association between sun exposure and changes in serum $25OHD_3$, and how this varies with age, skin pigmentation, latitude and season. At the time of the workshop, preliminary data were available from only about half of the total number of people surveyed for presentation in this report.

Study design

The study related UV exposure to vitamin D level measured twice, once after 4 weeks and again after another 4 weeks of UV exposure measurement. The potential UV exposure was measured by a dosimeter worn like a watch on the wrist, above any clothes. The measure of exposure used in these analyses is this recorded measure which is then multiplied by the proportion of skin exposed. Each participant, for the 8 weeks of the study, recorded the clothes they were wearing for each of three periods each day (up to 11 am, 11 am to 4 pm and after 4 pm). The cumulative UV exposure in each of these periods was multiplied by the proportion of the skin exposed and averaged over the 4 weeks to give a measure with the units of SED/day. To obtain a wide range of UV exposures the study was conducted over a wide seasonal range (February to November) and in two centres with quite different latitudes.

In 2008, 250 participants recruited from work places and the community, aged 18 to 81 years, from a wide-range of ethnicities (Maori, Pacific, Asian and European) were enrolled into the study, (164 in Auckland (36° 52′ S) and 86 in Dunedin (45° 50′ S)) and 239 have complete data which has been used for demonstration analyses in this presentation. The observation time for these participants is evenly spread over the year, except for summer when there were very few observations.

Simple linear regression and linear mixed models have been considered as possible analysis techniques. The simple association of UV exposure over 4 weeks with the level of vitamin D at the end of that period is a simple possibility. This model needs all confounding variables to be included to get the appropriate assessment of UV exposure. To reduce the effect of subject variation, the change in vitamin D level from the 4 week to 8 week measure can be associated with UV exposure. To use all the collected data a more complex model, a linear mixed model, can be used. This model has two UV exposure and two vitamin D measures for each individual. The UV exposure data are modelled as fixed effects in the model and the subject variation is modelled by including subject as a random effect. The UV exposure can be modelled as the observed exposure during each of the 4 week intervals or it could be modelled with the two variables, the UV exposure mean for each subject and the deviation of the observed exposure from this mean (Neuhaus & Kalbfleisch 1998). This enables examination of the within and between subject effects.

Results

As expected, both UV exposure and vitamin D levels vary by time of year (Figure 1).

In the winter months there is very little UV exposure as recorded by the participants of this study and so very little variation. The vitamin D level also drops during the winter months and for 2 months none of the participants had a vitamin D level above 75 nmol/L.

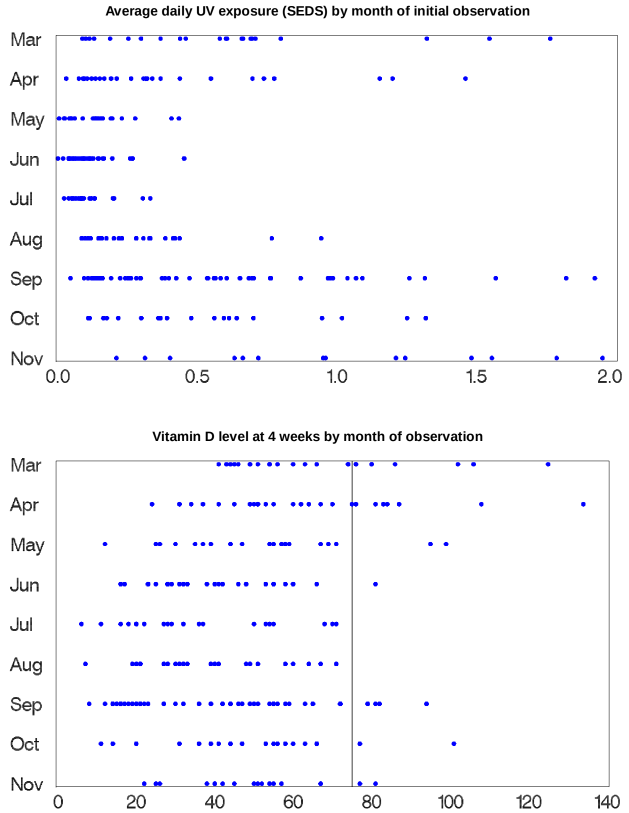

Figure 1. Upper panel: The average daily exposure (SED/day) by month of the year of initial observation. Lower panel: The vitamin D (nmol/L) reading after 4 weeks in the study by month of the year of initial observation.

The simple regression assessing the 8 week vitamin D level shows a strong relationship with UV exposure, but this is strongly influenced by individual characteristics. To obtain a satisfactory estimate of effect, all the confounding variables need to be included in the model. The assessment with change in vitamin D showed a positive but small relationship; for an exposure increase of 1 SED/day the vitamin D change between measurements would by 6.9 (3.5). Because we are assessing a within subject measure, the effect of between subject differences is removed. The mixed model has the two terms, mean UV exposure and the deviation of the observed UV exposure from the mean. In this case, there being only two observations, one deviation is the negative of the other. As the mixed model includes the random subject effect and the mean exposure level is included as a fixed effect this leaves the deviation to describe the effect of a within person UV exposure. In the demonstration data this effect is 5.9 (4.4) (Figure 2). The coefficient of the mean effect is 37 (7) which reduces to 24 (6) when a number of subject specific covariates (ethnicity, skin colour, BMI and time of year) are included in the model.

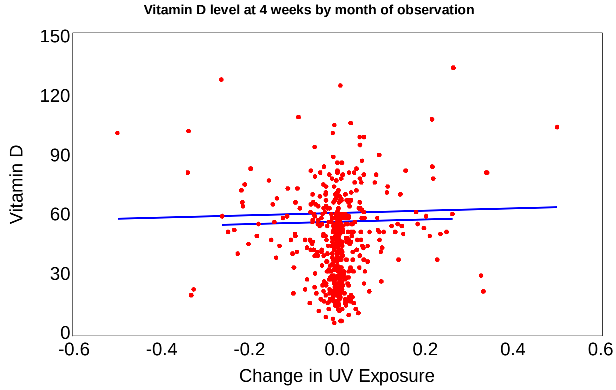

Figure 3. The predicted regression line (Auckland – upper and Dunedin – lower) associated with the deviation from the mean vitamin D level. The slope of this line is 5.9 (4.4) SED/day. The points are the observed deviations. These points are similar to but not quite a reflection about 0 as they come from the measured vitamin D values at 4 and 8 weeks of observation.

Discussion

Models that remove subject effects by use of confounder variables show a much greater association between UV exposure and vitamin D levels. This is probably because we have recorded only some of the confounder variables and those we have are not accurately measured. The models that remove the subject effects by use of the vitamin D levels themselves show a lower level of association and are reasonably consistent. However, it could be that there is a different effect of UV exposure between individuals compared with that within individuals over time. We need to ensure that we use an appropriate model, one that removes the subject effect, in our reporting of the results from this study.

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Vitamin D in Brisbane office workers

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Abstract. Vitamin D is necessary to maintain healthy bones, and may play a role in prevention of other chronic diseases such as cardiovascular disease and cancer. The main source of vitamin D is exposure to solar ultraviolet radiation. Individual vitamin D status is generally determined by measuring the serum 25-hydroxyvitamin D (25(OH)D) level. There is limited information about vitamin D levels in the Australian population. We therefore measured serum 25(OH)D levels in a group of office workers in Brisbane. At the end of summer the mean 25(OH)D of 129 participants was about 74 nmol/L, and 14% of participants had insufficient vitamin D levels (using a cutoff at 50 nmol/L). At the end of winter the mean 25(OH)D of 175 participants was 54 nmol/L and 51% of people were vitamin D insufficient. Time outdoors out of peak UV times was associated with serum 25(OH)D in summer, while higher vitamin D intake was associated with higher winter serum 25(OH)D levels.

Introduction

Vitamin D, also known as the 'sunshine vitamin', is generally acquired in human skin through exposure to solar ultraviolet (UV) radiation. Adequate vitamin D levels are essential for maintenance of bone health, but there has been increasing research in the past decade into other possible benefits of vitamin D.

Individual vitamin D status is generally determined by measuring the serum 25-hydroxyvitamin D (25(OH)D) level. There is some debate about the optimal vitamin D level for health. Currently 25(OH)D below 25 nmol/L is considered to be deficient, and less than 50 nmol/L as insufficient. However it has been suggested that 75 nmol/L, or even 100 nmol/L, should be the target level in human populations.

Notwithstanding uncertainty about the appropriate vitamin D level, many studies have shown that vitamin D deficiency is prevalent worldwide, particularly during winter. In Australia, low vitamin D levels have been reported in various population subgroups, including people in residential care, recently arrived migrants, and Muslim women. Suboptimal vitamin D levels have also been documented among free-living adults living in environments with high solar UV radiation levels. A broad array of factors has been shown to influence individual vitamin D levels, including both environmental and personal characteristics and behaviours, but these are likely to vary depending on the population under study.

There is a paucity of information about vitamin D levels in people who work mainly indoors and who are presumably at risk of vitamin D deficiency due to limited opportunity for exposure to solar UV radiation. We therefore conducted this study to ascertain the vitamin D status in summer and winter of indoor office workers and to examine factors that independently affect vitamin D levels of this population. This knowledge is necessary for the development of appropriate public health recommendations for this subpopulation.

Methods

Brisbane-based employees of Suncorp (a large banking and insurance organisation) were invited to participate in an online survey in which sun exposure and sun protection and knowledge and attitudes about vitamin D were ascertained. A subgroup of survey participants was invited to participate in a second phase of this study in which vitamin D levels were measured. The response rate for the survey was about 70%. Half of those selected to participate in the blood collection phase of the study agreed to participate, but for logistic reasons we only collected blood from 60% of these. 129 participants took part in the summer blood collection, 175 in the winter collection, and 91 in both.

We asked participants to complete a questionnaire in which they recorded their time outdoors during the day, their sun protection behaviour, and their vitamin D intake from food and supplements over the past month.

Serum 25(OH)D was measured using a Diasorin Liaison platform. The instrument was calibrated based on two calibration points (in triplicates) at 10 and 187.5 nmol/L. Samples from the Vitamin D External Quality Assurance Scheme (DEQAS) were measured before analysis and the results were on average within ±5% of the DEQAS values

We used simple descriptive statistics to describe the distribution of vitamin D. We dichotomised 25(OH)D using 75 nmol/L as the summer cutpoint and 50 nmol/L as the winter cutpoint to allow for differences in the distribution by season and ensure adequate statistical power. Prevalence ratios (PR) were calculated to quantify associations with vitamin D insufficiency using log-binomial modelling in generalised linear models. To assess determinants of change in vitamin D levels from summer to winter, we used an ANCOVA model with the inclusion of baseline vitamin D level to adjust for the effect of regression to the mean (RTM).

Results

Serum 25(OH)D levels ranged from 33 to 129 nmol/L in summer (mean 74 nmol/L) and 14 to 94 nmol/L in winter (mean 54 nmol/L). In summer, 14% of participants had a serum 25(OH)D level of less than 50 nmol/L while in winter 51% were insufficient using this cut-off (Figure 1). Had a cut-off of 75 nmol/L been used, 54% of participants would have been considered insufficient at the end of summer and 87% at the end of winter (Figure 1).

There was a high correlation between summer and winter 25(OH)D levels (Pearson correlation coefficient 0.74) (Figure 2)

[1] Queensland University of Technology

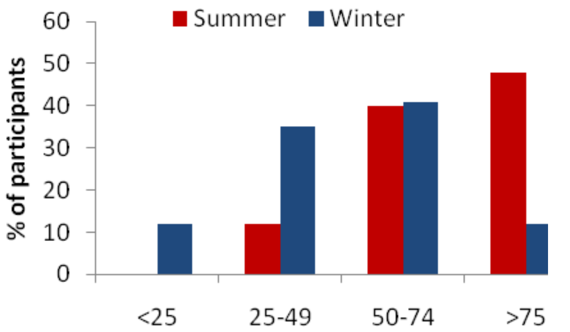

Figure 1. Distribution of participants according to serum 25(OH)D category.

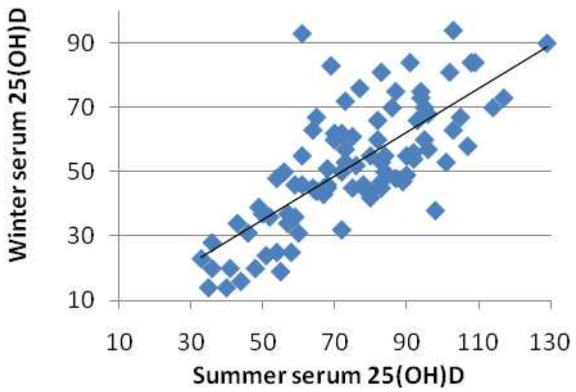

Figure 2. Correlation between summer and winter serum 25(OH)D levels.

Women had a significantly lower mean serum 25(OH)D in summer than men (68.1 versus 79.4 nmol/L, $p<0.01$), and were about 60% more likely to have a serum concentration of less than 75 nmol/L (PR 1.61 95%CI 1.15–2.26, adjusted for age). This trend was also observed in winter, although it was not statistically significant. Compared with people who had no skin cancer history, those with a history of non-melanoma skin cancer appeared to have a lower risk of having insufficient vitamin D levels in summer (PR 0.72 95%CI 0.52–1.00 using a cut-off of 75 nmol/L) and in winter (PR 0.58 95%CI 0.39–0.85 using a cut-off of 50 nmol/L in) in comparison with those without this history.

In summer, spending 1 hour or more outdoors per day before 9 am or after 3 pm at the weekend was significantly associated with increased 25(OH)D concentrations compared to sun exposure of less than 1 hour per day at these times (77.4 versus 65.7 nmol/L, p 0.004). Having sunbathed to deliberately obtain a tan in the past 12 months was also associated with increased serum levels in summer; those who had not sunbathed were at more than twice the risk of having serum 25(OH)D less than 75 nmol/L. Although not significant, people who spent less than 1 hour outside each day on weekend days before 9 am or after 3 pm were more likely to be vitamin D insufficient than those who spent more time than this outside (PR 1.31, 95% CI 0.92–1.86).

There were significant differences in serum 25(OH)D concentrations according to the type of clothing worn, particularly in winter. People who often wore full-length clothes (long-sleeved, full-leg) during non-work days in winter had about a 50% increased risk of having 25(OH)D less than 50 nmol/L compared to those who wore shorter-length clothes (short-sleeved/ sleeveless, half-leg). No significant difference in 25(OH)D was found between those who used and did not use sunscreen. Diet was associated with 25(OH)D concentrations only in winter, with those who obtained less than 10 µg of vitamin D from foods and supplements per day being at higher risk of vitamin D insufficiency (PR 1.53 95%CI 1.03–2.27).

The mean change in vitamin D levels from summer to winter was 22.8 nmol/L (95%CI 19.8–25.8). More than one-third of those with sufficient summer 25(OH)D (≥50nmol/L) became insufficient in winter (35%) and 4 people (5%) became deficient (<25 nmol/L). After adjusting for the regression to the mean effect in an ANCOVA model, significant predictors of change in serum 25(OH)D between summer and winter included winter vitamin D intake and smoking status .Compared to those with winter vitamin D intake less than 10µg/day, those who consumed 10µg/day or more had a 8.43 nmol/L smaller change in 25(OH)D concentrations over the summer to winter period (17.74 versus 26.17 nmol/L, p= 0.002). People who never smoked had a 6.08 nmol/L smaller change in 25(OH)D than those who were past or current smokers (18.91 versus 24.99 nmol/L, p=0.02). The model could explain 31% of the variation in the change of serum 25(OH)D concentrations over this summer-winter period (adjusted R^2 0.306).

Discussion: These data show a relatively high prevalence of vitamin D insufficiency in this population of office workers living in a subtropical climate. Given that about 40% of participants had 25(OH)D levels between 50 and 75 nmol/L, the cutoff used to define insufficiency will play a major role in determining what proportion of the population is considered to be insufficient. However even using the current cutoff of 50 nmol/L, over 40% of people were vitamin D insufficient at the end of winter.

Current recommendations suggest that for most people incidental sun exposure is sufficient to maintain vitamin D levels all year in Queensland. Our data suggest that this may not be the case for this population group. However we found that vitamin D intake was associated with winter serum 25(OH)D levels, and that higher intake resulted in a smaller change from summer to winter. Until more information is available about the relation between sun exposure and vitamin D production at different times of the year and in people with different skin types, winter vitamin D supplementation might be an appropriate strategy to ensure optimal vitamin D levels are maintained in indoor workers.

Action spectra for UV effects – UV filtering by human skin

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Abstract. Human skin is the interface between man and his environment. One of the environmental factors it has to deal with is ultraviolet radiation. Ultraviolet radiation may cause negative effects such as erythema, skin ageing, skin cancer, etc. Not surprisingly, the epidermis – the upper layer of the skin – acts as a natural UV filter and may thicken or develop a stronger pigmentation as an adaptation to excess UV exposure. On the other hand, UV radiation induces photoproduction of previtamin D_3 in the skin and thus provides the major natural source for vitamin D_3 for humans. Thus, it seems reasonable that skin has not evolved as a mere sun block but as a sun screen which is even adaptable to a certain extent. Using optoacoustics, we have determined the wavelength dependent absorption coefficients of human skin in the UVB and UVA-II. Based on these data for the UV filtering properties of human skin, we calculated the biological effectiveness of solar radiation at different depths within the epidermis and found that UV adaptation more effectively shields the skin from erythemally active radiation than from vitamin D producing radiation. Thus, adaptation to high UV exposure tends to choose beneficial over detrimental UV effects.

Optoacoustic study

Optoacoustics is a fairly new method for studying the optical properties of human skin in vivo. Pulsed laser radiation is used to illuminate a sample of the skin. The radiation is distributed in the sample according to its optical properties and absorbed radiation energy is converted to pressure. This pressure profile (high pressure where a lot of radiation has been absorbed and low pressure at volumes with low absorption) is released as an ultrasound pulse and can be measured above the skin. The initial light distribution in the sample and its optical properties can be deduced from this ultrasound pulse.

We measured the absorption spectra of human skin in a study in 20 subjects belonging to skin phototypes I–IV (phototype I: n=3, phototype II: n=6, phototype III: n=6, phototype IV: n=5). Absorption coefficients were determined in the range from 290 nm to 341 nm (3 nm steps) on the inner and outer side of the forearm and the ball of the thumb. The study was conducted in the summertime and 12 subjects reported sunseeking behaviour whereas the other 8 subjects said they were office workers and tended to avoid sun exposure.

The optical properties that human skin develops depend on individual native and environmental parameters. Environmental effects may be facultative pigmentation and a thickened horny layer in response to and as an adaptation to higher UV exposure. Because the skin on the inner side of the forearm is relatively thin and normally only weakly exposed to daily sunlight, it is expected to show nearly the native properties of individual skin. On the outer side of the forearm, the skin is much more strongly exposed to sunlight and UV radiation but the skin structure is still similar to that on the volar side. Comparative analysis of these two sites allows insight into how UV adaptation may affect the optical properties of the skin.

Optical properties of skin

Figure 1 shows the absorption spectra of human skin at different skin sites: inner and outer side of the forearm – i.e., skin with low and high natural UV exposure – and the ball of the thumb where the skin's horny layer is especially thick. Data for the outside of the forearm is shown as mean as well as split into the high and low UV exposure group. Remarkably, the horny layer is a potent UVB screen but is fairly transparent to UVA radiation. Adaptation to higher UV exposure results in higher absorption coefficients, especially in the UVB range, probably due to epidermal. thickening and pigmentation.

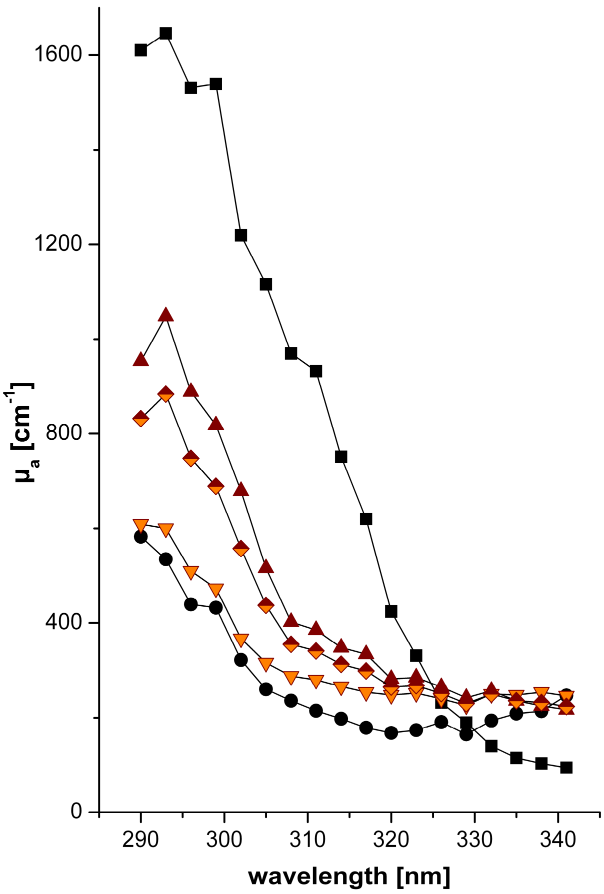

Figure 1. UV absorption spectra from different sites of human skin: inner side of the forearm (black circles), outer side of the forearm (mean: bi-colour diamonds, low UV exposure group: downward triangles, high UV exposure group: upward triangles) and ball of the thumb/horny layer (squares).

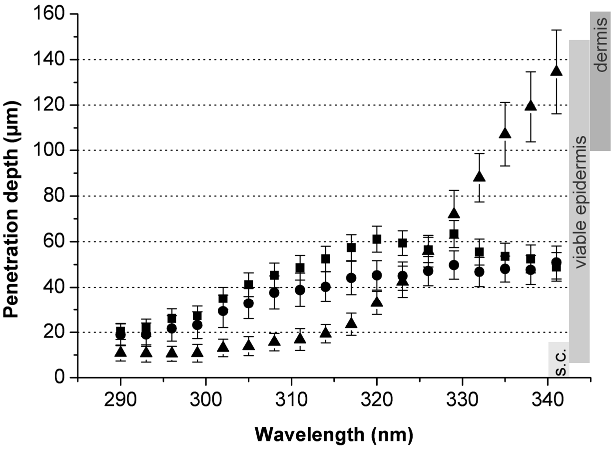

Figure 2. Penetration depths (1/e-level) of UV radiation for human skin at the volar side of the forearm (squares), dorsal side of the forearm (circles), and at the ball of the thumb (triangles).

Figure 2 shows what these absorption spectra mean in terms of penetration depth. In normal skin, as on the forearm, UV radiation is strongly attenuated. Only 40% or less of the incoming radiation reaches a depth of 60 µm – halfway through the viable epidermis. The horny layer very effectively reduces the penetration depth for UVB radiation. A thickened horny layer thus provides an effective screen for the living cells underneath it. On the other hand, it is ineffective in blocking UV radiation.

UV filtering and UV effects

To assess the UV filtering potential of human skin, we calculated how much of the diffuse solar spectral irradiance weighted by the action spectrum for erythema or previtamin D_3 formation penetrates 20 and 100 µm deep into human skin based on its optoacoustically measured optical properties.

Applying a simple model like the Lambert-Beer law, the global spectral irradiance E(λ) is attenuated exponentially with increasing depth d according to the skin's optical properties (μ_a). This attenuated spectrum is weighted by the respective action spectrum A(λ) and integrated over the relevant wavelength range yielding the biologically effective irradiance at the respective depth:

$$E_{bio}^{skin} = \int_{290nm}^{345nm} E(\lambda) e^{-\mu d} * A(\lambda) d\lambda$$

Figure 3 shows the difference between $E_{erythema}$ ($isE_{erythema}$) and $E_{previtaminD3}$ ($isE_{previtaminD3}$) for two depths within the skin, weakly pigmented vs. UV adapted skin, and for global spectral irradiances from SZA 30°, 50° and 70° as would be expected for summer, autumn/spring, and winter at temperate latitudes. Only when the sun is low, vitamin D_3 is produced throughout the skin before the minimal erythemal dose is reached. Erythema outweighs vitamin D_3 production for the rest of the year in weakly pigmented skin. The cumulative UV-screening effect of the skin chromophores becomes, of course, more and more effective with increasing path length – i.e., depth – in the skin. At the basal layer, where protection from detrimental UV effects is most important, the full impact of the filtering properties of UV adapted skin is unveiled: 100 µm of UV adapted skin can shift the dominant effect of UV radiation from erythema to vitamin D_3 production.

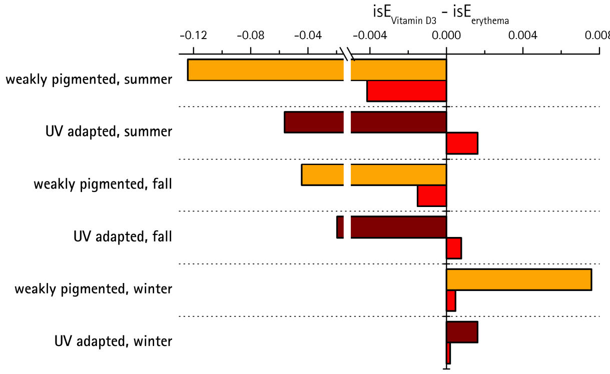

Figure 3. Difference between the biologically effective irradiance of one detrimental UV effect ($E_{erythema}$ ($isE_{erythema}$)) and potentially beneficial UV-induced vitamin D_3 synthesis ($E_{previtaminD3}$ ($isE_{previtaminD3}$)). Combinations of solar spectral irradiance from three different SZA and two UV adaptation status of the skin are compared. The upper bar in each row is for a depth of 20 µm within the skin and the lower bar (in red) shows the situation at a depth of 100 µm near the basal layer at the dermal-epidermal-junction.

It is important to note, however, that the action spectra used for this calculation can give only a rough idea of the true in vivo situation. The action spectrum for previtamin D_3 production for example marks the dose where 5% of provitamin D_3 is converted to previtamin D_3. It is not clear what this means in terms of vitamin D_3 sufficiency. Besides, all action spectra are based on single dose administration, but the factor of time is very important in the in vivo situation. For example, repair mechanisms may take their time to counteract detrimental UV effects. On the other hand vitamin D_3 may just accumulate over time.

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Seasonal vitamin D

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Abstract. A fundamental assumption when undertaking studies into vitamin D and populations is that the relative "ranking" of an individual remains constant with respect to time. That is, an individual with a low ranking (lowest percentile) of vitamin D status in summer will also have a low ranking (lowest percentile) of vitamin D in winter, even though the vitamin D status may have increased from summer to winter. This work investigates if such relative ranking exists in populations and what impact this assumption has on epidemiological research

Introduction

Occurrence of many cancers, autoimmune diseases and infections varies geographically by latitude, as do levels of ambient ultraviolet radiation (UVR) (Holick 2004a). There is some supportive animal experimental and laboratory evidence to suggest that vitamin D insufficiency, presumably over some sustained period, may be an important risk factor in the etiology of these conditions (Holick 2004a). In their landmark report (WHO 2008) the International Agency for Research on Cancer (IARC) further supported this vitamin D insufficiency–disease hypothesis by identifying vitamin D as a possible cancer prevention agent.

In individual-level studies, which have provided mixed support for the vitamin D insufficiency – disease hypothesis, vitamin D status (measured as serum concentration of 25-hydroxyvitamin D (25(OH)D)), has usually been based on a single blood sample. In order to compare 25(OH)D levels from samples taken at different times in the year, studies attempt to statistically remove any background seasonal variation (due to changing UVR levels) by estimating each sample's deviation above or below the mean seasonal curve. This assumes that an individual maintains their position relative to the mean throughout the year. If this assumption is incorrect (and there is some preliminary evidence to suggest it is), a single 25(OH)D level may provide little information on "average" vitamin D status, with this measurement error resulting in null findings.

Based on seasonal variation in ambient UVR and in sun exposure behaviour, seasonal variation in 25(OH)D levels is expected. Indeed, at the population level, there is clear evidence that the population mean follows the expected pattern through the year (Webb et al. 1989, Holick 2004b); however, the few studies that have examined individual vitamin D status across more than one time period suggest that there is substantial intra-individual variation in seasonal variability (e.g., in Japanese (Nakamura et al. 2000) (r=0.46) and Canadian (personal communication) (r=0.38) women, there was a poor correlation between winter and summer 25(OH)D levels).

Most individual-level epidemiological studies examining vitamin D status in relation to disease risk measure serum 25(OH)D levels at a single time point, statistically "adjusting" for seasonal effects based on the mean seasonal variation in 25(OH)D levels in the whole sample. In longitudinal studies, more than one pre-existing blood sample may be used, but in comparing either intra-individually or inter-individually, adjustment for season is still usually required, as logistic considerations mean that samples are taken at different times of the year. However, if there is a poor correlation between winter and summer 25(OH)D levels (as noted above), then such adjustment, based on an individual maintaining their relationship to the mean, may not be valid.

Methods

The 25(OH)D levels of 60 healthy ambulatory adults (42 female) aged 18 to 87 (median 49) years, in southeast Queensland, Australia (27° S) were tracked from winter to summer. After informed consent, participants were administered a questionnaire surveying past (previous 30 days) sun exposure, timing of sun exposure, sun protection used and dietary vitamin D intakes.

Serum 25(OH)D was measured at the Queensland University of Technology using a high throughput Diasorin Liaison competitive binding chemiluminescence system. This system was calibrated with control standards before use and participates in the DEQAS programme (Vitamin D External Quality Assurance Scheme)

Data were analysed using the Statistical Package for Social Sciences (PASW) software package v18.0 (SPSS 2005). Descriptive univariate and bivariate analyses of associations between serum 25(OH)D, personal characteristics, sun protection practices are reported.

The responses from the participants were used to identify potential explanatory variables for the variation in seasonal 25(OH)D, with a backwards elimination process in a univariate General Linear Model. For this model, the following independent variables were used: age, gender, education, BMI, PTH, self-reported hair colour, self-reported skin colour, self-reported eye colour, self-reported burning tendency, self-reported tanning tendency, self-reported previous 30 day weekday (occupational) sun exposure, self-reported previous 30 day weekend (recreational) sun exposure, self-reported previous 30 day sunscreen use, self-reported previous 30 day hat wearing, self-reported previous 30 day long-sleeved shirt and self-reported previous 30 day long trousers wearing, and the objective measures of inner upper arm L*, dorsum right hand L*, and mid-forehead L*.

Additional indicators of the previous 30-day intake of vitamin D rich foods, such as oily fish and oral supplementation and fortified milk, was used in this model (at least 4 times in the last month yes/no). Non-significant explanatory variables were sequentially removed if the lowest F-statistic was less than 4. The standardised residuals for this final model of 25(OH)D had a mean of zero and were within +/- 2 standard deviations of the mean.

Results

The blood serum 25(OH)D status of the participants in this study ranged from 17 to 128 nmol/L in winter (mean 59 nmol/L) and 16 to 130 nmol/L in summer (mean 76 nmol/L). Gender differences ($p=0.05$) were observed between females ($n=42$) having a winter status range of 17 to 142 nmol/L (mean 60 nmol/L) while males, for the same season, had values ranging from 19 to 147 (mean 72nmol/L). Similarly in summer, females had a lower 25(OH)D status then males ($p=0.001$) with a mean of 71.6 nmol/L (range 12 to 109 nmol/L) compared to the males mean of 85 nmol/L (range 52–130 nmol/L). Body mass index and serum intact parathyroid hormone serum was negatively correlated with 25(OH)D status (-0.323 $p=0.05$ and -0.312 $p=0.015$ respectively). Figure 1 shows the summer and winter comparisons of the study cohort.

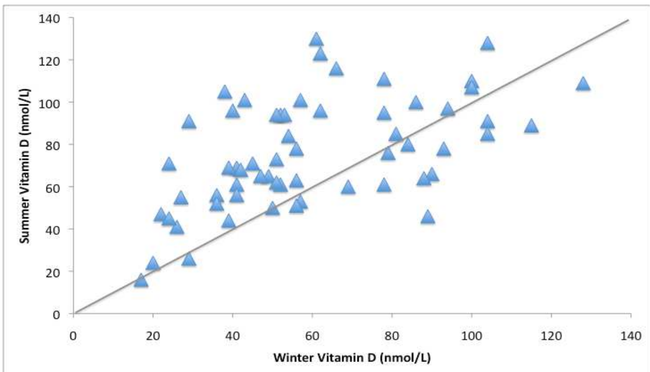

Figure 1. Relationship between vitamin D status in summer versus winter.

No significant relationships were found between self reported time outdoors in the sun and 25(OH)D status both for the summer and winter seasons. This included the total time in the sun and also time spent outdoors in hourly time intervals. Summer 25(OH)D status was positively correlated ($p=0.003$) with sunscreen use whilst in winter no similar relationships were found.

Melanin density was calculated using measurements of skin spectral reflectance. The change from winter to summer in values located at a high UV exposure site, in this case the forehead, was used to estimate the tanning response of an individual. A positive correlation between seasonal changes in forehead melanin density (winter to summer) was found for 25(OH)D status (0.417 $p=0.001$). The amount (expressed as a percent) of skin exposed caused an increase in 25(OH)D status by 0.703 nmol/L for every 1% increase in amount of skin exposed.

The model could explain 31% of the variation in the change of serum 25(OH)D concentrations over this summer-winter period (adjusted R2 0.306).

Discussion

The data presented suggest that the relative ranking of vitamin D from summer to winter changes for a population based in SE Queensland. Interestingly, for some individuals who have high winter vitamin D status, they can, move to a low summer vitamin D status. The results indicate that little is understood of the determinants of seasonal vitamin D status on an individual and population based level. Further investigations into the role of sun exposure, skin type and genetic factors involved in seasonal vitamin D status is warranted.

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The increasing incidence of melanoma: the role of MelNet

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Abstract. The incidence of melanoma in developed countries, including New Zealand, has increased dramatically over recent decades and at a faster rate than most other cancers. Although potentially fatal, optimal outcomes are obtained with early detection and adherence to evidence based treatment. To improve the outcomes of persons with locally advanced or disseminated melanoma, effective translational research is required. Following publication of the Clinical Practice Guidelines for the Management of Melanoma in Australia and New Zealand, the Melanoma Network of NZ (MelNet) was established to reduce the incidence and impact of melanoma in New Zealand. MelNet provides a forum for professionals working in any area related to melanoma. This includes a website and biennial conferences. MelNet has ongoing projects to implement the guidelines.

Melanoma

Melanoma (previously called "malignant melanoma") is a type of skin cancer, named for its usual dark melanin pigment. By contrast to the slow growth and indolent behaviour of more common skin cancers, melanomas are frequently aggressive in their growth and may spread to the regional lymph nodes and to distant organs.

The majority of melanomas arise sporadically in exposed skin. Exposure to ultraviolet radiation is strongly implicated in the aetiology of melanoma. There is an association with BRAF mutations in sporadic melanoma. A small proportion has a familial pattern with mutations in genes including CDKN2A, P16INK4A and P14ARF.

Incidence of melanoma in New Zealand

New Zealand and Australia share the unenviable reputation for the highest melanoma incidence globally. The main points regarding incidence in New Zealand are:

- The incidence has increased greatly over the past 50 years but is showing signs of plateauing (~2000 cases and ~300 deaths in New Zealand in 2004)
- Lifetime risk 1:13 for males, 1:18 for females
- Although predominantly a disease of the elderly, the rate rises steadily from early adulthood (most common cancer in males 25–40 years and females 15–25 years)
- The incidence in Maori and Pacific peoples is very low.

A number of factors have been shown to correlate strongly with incidence. These include multiple naevi, previous melanoma, family history of melanoma, fair complexion, history of severe sunburn, older age and male gender.

Factors affecting outcome of melanoma

Several variables correlate strongly with prognosis. For primary melanoma (stage I/II), increasing Breslow thickness (total vertical thickness of melanoma measured in millimetres), increasing mitotic count and the presence of ulceration indicate a worse prognosis. Accurate diagnosis at an early stage and adequate removal provides a high chance of cure.

For locally advanced (stage III) melanoma, increasing number of involved lymph nodes carries a worse prognosis. Translational research that leads to an effective adjuvant systemic therapy is urgently needed for this group.

Persons with disseminated melanoma (stage IV) are essentially incurable. The efficacy of recently developed BRAF inhibitors demonstrates the benefits of translational research and rational drug design., with clinical results indicating over 70% response of tumours with the E600 mutation.

Clinical practice guidelines

The publication in 2008 of clinical practice guidelines (abbreviation "the guidelines") as a Trans Tasman project was a major achievement and represents the first international clinical melanoma guidelines. The guideline development process involved collaboration between the Australian Cancer Network (ACN), the Cancer Council (Australia) and the New Zealand Guideline Group. Oversight of the New Zealand perspective was undertaken by the NZ Melanoma Reference Group, with membership including health professionals, Maori and Pacific people, and consumers.

Within New Zealand, the availability of this evidence based guideline provides a template for service improvement mapping and for audit of management.

The Melanoma Network of NZ (MelNet)

MelNet was established in 2008 at the conclusion of the Melanoma Summit, which was the first attempt to bring together all workers interested in an area related to melanoma, and marked the launch of the guidelines. This includes scientists, health promoters, health professionals and policy makers in many disciplines. MelNet arose from the clear need for an umbrella organisation to represent, link and support these disparate groups.

MelNet has an executive for governance and is supported by the Health Sponsorship Council (HSC) and the Melanoma Foundation of NZ.

The value of MelNet exceeds its immediate role to facilitate communication between diverse work areas, with a dedicated website (www.melanoma.org.nz/melnet), mailouts, biannual national meetings and a database of members. MelNet is also actively involved in implementing critical recommendations of the guidelines.

MelNet identified the following topics as its initial projects:

- upskilling of dermascopy
- tissue-banking melanoma specimens for translational research
- development of a national melanoma database
- improved patient communication.

MelNet is also a key partner in a MOH-sponsored project for an implementation plan for the guidelines. Important additional areas for implementation include compliance with the guideline regarding excision of primary melanomas and use of a standard synoptic pathology report.

Through its varied roles across the spectrum of melanoma biology and the continuum of care of New Zealanders with melanoma, MelNet is well placed to face the challenge of increasing numbers of melanoma diagnoses.

The next national MelNet meeting will be 11 March 2011 in Wellington.

Acknowledgments

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Maximising protection — sun protective fabric and clothing

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Abstract. UV protection programmes promote the message to cover up and minimise exposure of skin surfaces to the sun. However, from a consumer's perspective what information is available to support selection of garments that will optimise protection? UPF rating provides information about fabrics that have achieved high ratings for protection, and, by implication, indicates that garments made from these fabrics will minimise exposure. However, most clothing and textile products are not tested and do not carry UPF ratings. When purchasing such garments what product characteristics are important?

UV intensity and sun protective clothing

Credited with the highest rates of skin cancer in the world New Zealanders and Australians are increasingly aware of the health risks associated with overexposure to UV radiation. The need to slip, slop, slap and wrap has been extensively promoted, along with the importance of utilising shade and personal shade (including clothing) during high UV index times of day and year.

A number of national standards using rating systems are recognised as indicating UV protection capacity provided by fabrics. Such rating systems enable manufacturers to label and promote garments made from UPF rated fabric as being sun protective clothing. UPF swing tags can be used on garments rated as sun protective by accredited programmes such as ARPANSA (Gies et al. 1994)

In spite of the promotional programmes and awareness of rating systems most clothing worn during the high UV exposure months is not UPF rated. Consumers are either choosing UPF rated garments for certain activities only, actively choosing not to purchase UPF rated garments, or are selecting clothing on the basis of non-UV related criteria, e.g., fashion, life style etc.

From a consumer's perspective, what is 'sun protective clothing'? An increasingly common source of consumer information about 'sun protective clothing' is the internet; 'Googling' highlights the extensive use of the term. The majority of entries related to promotion and sale of SFP or UPF rated clothing as opposed to advice on how to make informed choices between similar clothing items Such items may provide very different levels of UV protection. Examination of the Wikipedia entry for sun protective clothing defines Sun protective clothing as "clothing specifically designed for sun protection and is produced from a fabric rated for its level of ultraviolet (UV) protection." Further examination of the search results led to official websites of organisations such as the Cancer Society (NZ) which provides one of the more informative information sheets detailing factors consumers should consider when buying clothing to enhance their overall UV protection (Cancer Society 2007). While last reviewed in 2007 this information sheet carries the cover up message, provides information on the UPF and the UVI, and basic guidelines for choosing the "best type" of fabric (i.e., advice regarding fabric weave, colour, weight, stretch and wetness).

However, guidelines for selecting the best fabric and garments (other than reference to UPF ratings) are difficult to find. How has our understanding of factors affecting protection provided by fabric and clothing progressed from 2007 to now? Can we improve recommendations about key factors (e.g., fibre, yarn, fabric and wear) affecting protection provided by fabrics and garments?

Social and environmental factors other than UV also affect summer clothing selection. Warmer temperatures increase preference for clothing of lighter mass, greater air and water vapour permeability, and lighter colour. Thermal comfort/thermophysiological needs are often at odds with selection of clothing that will provide greater UV protection. Is it possible to balance thermo/physiological and UV protection needs?

Structure — woven or nonwoven

Much consumer advice focuses on woven textiles, stating that the weave of fabrics should be tight as such fabrics provide better protection than loosely woven ones. Yet textiles are available in a variety of structures, e.g., woven and nonwoven (knitted, fibre mats, films such as neoprene, etc.) with knitted fabrics increasingly used for production of products promoted as suitable for active outdoor and summer wear, e.g., Icebreaker; Silkbody, etc.

The accepted rule is that the higher the cover factor the greater the UPF regardless of fabric structure. When fabrics with the same cover/tightness were examined a hierarchy of weave structures, in order of increasing UPF, was identified: i.e., plain, twill, satin (Dubrovski et al. 2009); like the twill, jersey was associated with lower levels of transmission (Wilson et al. 2008). Differences between plain and twill weaves are attributable to the floating of weft (crosswise) yarns, over one and under two of the warp filling threads creating greater cover/density in twills (Taylor 1995).

However, this relationship is not linear and is instead dependent on the colour of the fabric and other factors, e.g., extensibility, which affect the size of the interstitial spaces. More extensible fabrics will require higher set, effective recovery, and garments styled to ensure positive rather than negative ease, in order to maintain protection during use.

Colour

Preference for lighter colours in summer is associated with greater reflection of the infra-red (IR) part of the light spectrum (Shkolnik et al. 1980, Dubrovski & Golob 2009). While perceived as cooler, lighter colours result in increased UV transmission as the greater the 'depth' of colour the better the resulting UV protection (Wilson et al. 2008). Many light colours can not be produced with sufficient depth to provide adequate levels of protection. Interactions between cover and colour suggest that choosing a fabric in a lighter colour with a tighter sett or higher knitting stiffness (smaller gauge needles) may partially offset the effect of colour alone. High temperatures in the clothing layers may be offset using appropriate fabric (e.g., selected fibre types), air (AP) and water vapour (WV) permeability and design decisions (e.g., loose fitting, well ventilated garments), so that while clothing temperature increases, skin temperature does not (Shkolnik et al. 1980).

Air and water vapour permeability

Choosing fabrics with structures and set/knitting stiffness associated with small interstitial spaces has implications in terms of AP and WV permeability. Low AP and water vapour permeability are associated with greater discomfort. However, alternative pathways for air and WV venting facilitating microclimate and environmental exchange (e.g., loose fit; larger sleeve volumes; selection of hydrophilic ('natural') rather than hydrophobic (synthetic) fibres, or use of hydrophilic finishes) may improve physiological comfort.

Natural, synthetic or blended fabric

Synthetic fibres are more permeable than natural fibres. Differences in UV transmittance through natural, synthetic or blended high UPF fabrics were shown to depend on fibre classification (found for UVA and UVR transmission only) Natural and blended fibre types transmitted significantly less UV than synthetics, yet while the natural fabrics were significantly heavier the synthetic and blended fabrics did not differ significantly in their mass (Wilson et al.). That polyester provides better protection than nylon or cotton (Hilfiker et al. 1996, Reinert et al. 1997) was not apparent in the high UPF fabrics (Wilson et al. 2008). Further clarification is needed.

Mass and thickness

UPF has been shown to be strongly positively correlated with weight per surface unit and thickness of the fabrics (Algaba et al. 2008). However, the effect is dependent on other variables. For example, changes in thickness also need to be considered in terms of packing density and set/cover.

Garment style, surface area covered and conditions of use, e.g., quick drying

Style and conditions of use have also been identified as important contributors to reducing UV transmission and exposure, e.g., layering of fabric, wetting, fit, etc. (Wilson 2006, Wilson & Parisi 2006).

Single and multiple layer fabric arrangements become wet through exposure to: rain, wetting when swimming, etc. Wetting has been widely promoted as reducing a fabric's sun protection compared to that when dry (Gies et al. 1994). Yet differences in UV exposure will depend on the surface area wet, the degree of wetting (partial or saturated), and time to dry (Wilson & Parisi 2006). Consumers wanting to maintain protection need to consider: changing from wet clothing as quickly as possible, selecting clothing that will still provide an acceptable level of protection when wet, and/or selecting products that will dry quickly, e.g., synthetics which tend to dry faster than natural fibres (Gies et al. 1994, Wilson & Parisi 2006).

Conclusions

Consumers selecting products intended to maximise protection should be identifying fabrics that have been designed, and garments constructed, to maximise protection.

Improved understanding of the relationship between fibre, yarn and garment properties means that it is now possible to develop decision matrices to aid consumers in their choices while at the same time recognising that protection provided by textiles and clothing is confounded by interactions among variables. Informing the public on what fabrics, garments and wear practices are desirable is recommended.

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The Ultraviolet Index: health promotion tool or "poisoned chalice"?

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Abstract. At NIWA's 2006 workshop on ultraviolet radiation (UVR) and its effects, Billingsley and Milne (2006) outlined how the Ultraviolet Index (UVI) was used to communicate SunSmart behaviour and skin cancer risk to the New Zealand public. While the process of communicating the UVI both to the media, who were relied on to communicate the UVI, and to the public was described as 'challenging and complex', this effort was nevertheless described as having 'bridged the gap between science and health promotion'. However, evaluation and experience have since brought about a critical reappraisal of the UVI's effectiveness for communicating sun-protection messages. This paper compares the history of the UVI's development as a health promotion tool in New Zealand and Australia. The paper concludes that the trans-Tasman 'standardisation' of health promotion advice and messages based on the UVI needs to be considered.

Background

In the 1990s, burn time – a time-based measure of how long it would take fair skin to burn if exposed unprotected to direct sunlight – was used to communicate potential UVR risk to the New Zealand public. However, burn time came to be seen as an unscientific, poorly defined, and potentially dangerous concept (Bulliard & Reeder 2001). Pressure grew to replace burn time with the UVI to avoid confusion and align with international practice.

In 2002, the World Health Organization (WHO), together with the World Meteorological Organization, United Nations Environment Programme, and International Commission on Non-Ionizing Radiation Protection, launched a practical guide to the UVI (WHO et al. 2002). The organisations recommended that the UVI be adopted as a national and international measure to promote the 'global standardisation' of solar UVR risk behavioural messages. They also recommended the most effective ways of presenting UVI information, for example, by categorising different levels using colours and category names and adding behavioural cues.

UVI launched in New Zealand and Australia

Following the publication of the international guide, Kime and Reeder (2002) tested the UVI in New Zealand. The media, which would be relied on to communicate the UVI, initially expressed a preference for burn time, but eventually accepted the need to follow international recommendations, particularly once shown graphical examples of how the UVI could be communicated.

In 2003, the Health Sponsorship Council, the Cancer Society of New Zealand, NIWA, the MetService, and the University of Otago's Social and Behavioural Research in Cancer Unit formed an inter-agency working group. The group was to develop and promote the UVI as a communications tool for the New Zealand public. The group's objectives were to revise the WHO's UVI concept to 'fit' the New Zealand context; depict risk based on New Zealand's UVR levels; recommend sun-protective behaviours; and develop graphics for media weather reports and forecasts.

This collaboration resulted in the development of a UVI graphic (Figure 1) based on the familiar New Zealand fire-risk sign. This UVI graphic was then incorporated into TV One and TV 3's summer weather reports.

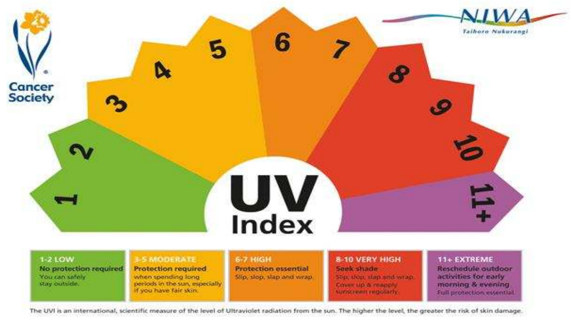

Figure 1. The new Zealand UVI display.

In contrast to New Zealand's UVI, the Australian SunSmart UV Alert is an indicator of risk that alerts people to the need for SunSmart behaviour (Figure 2). It identifies the specific period during which the UVI is forecast to reach 3 or above, and includes an approximate 'real-time' component by indicating forecast UVI levels throughout the day. Evaluation of the bell curve graph (in Figure 2) in Victoria, Australia, has nevertheless shown mixed results (Makin et al. 2007).

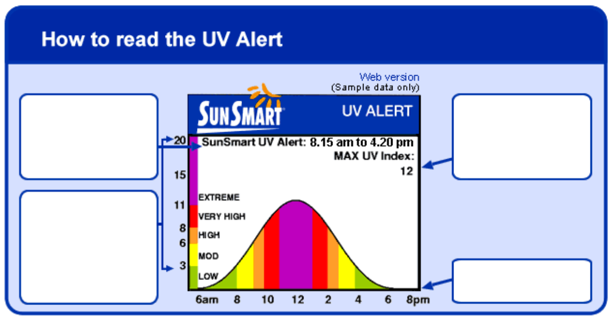

Figure 2. SunSmart UV Alert. BOM website. www.bom.gov.au/announcements/uv/.

Australian / New Zealand comparison

In New Zealand, there was also greater ambivalence among key stakeholder agencies about the appropriateness of broad population advice for sun protection when the UVI is 3 or higher (Galtry 2007). This was evident in various depictions of the UVI graphic with a static arrow pointing to 6, (e.g., ww.socialmarketing.co.nz/casestudies/UVIposter.pdf), suggesting that this approximate mid-way point (between low and extreme levels of 0-11+ in NZ context) is the recommended level for sun protection.

This possible ambivalence may reflect two factors. First is the commonly expressed view that it is unrealistic to advise sun protection when the UVI is 3 or higher, given that this is the situation for a large part of the day in most locations during the New Zealand summer. The WHO's practical guide was developed with particular reference to Europe, where peak summer UVR levels are much lower than those in New Zealand and Australia.

Second was the strongly emerging interest in the potential health effects of vitamin D and the important role of UVR (UVB) in facilitating vitamin D synthesis.

With increased emphasis on vitamin D, concerns have arisen about the need to inform people about safe and healthy sun exposure and, associated with this, the potential role of the UVI.

A key question is whether the UVI can also be used to inform people about appropriate sun exposure, thereby moving beyond its historical focus on sun protection (i.e., skin cancer risk) alone. Another question is, given evidence that people with different skin pigmentation require different amounts of UVR exposure to synthesise vitamin D, could UVI-related advice also refer to a variety of skin types.

Reassessment of sun-protection advice

Because of the uncertainties about and lack of consistency in UVI-related messages, the Cancer Society of New Zealand convened an interdisciplinary forum in 2008. The forum reassessed sun-protection and sun-exposure advice for New Zealand, including messages based on the UVI. Four key questions emerged.

- Is current advice to protect oneself from the sun when the UVI is 3 or higher correct? What evidence underpins this?
- Does the current UVI behavioural gradient make sense (i.e., if advised to protect oneself when the UVI is 3 or higher, do we need to use all five SunSmart steps at the same level)?
- Is a UVI under 3 the correct level to recommend increased sun exposure? What evidence supports this?
- Can the UVI be used to communicate individualised messages about safe and healthy sun-related behaviours for a variety of skin types?

The forum's key recommendations were to:

- maintain broad, time-based, sun-protection advice targeting the general population (i.e., to protect oneself between September and April, especially between 11 am and 4 pm)
- continue advising about the need for sun protection when the UVI is 3 or higher
- consider adopting the Australian UV Alert for communicating sun-protection messages (although it was agreed this required research, testing, and validation in the New Zealand context)
- consider a future forum to review advice for winter and for individuals with dark skin
- support further research on these issues.

In 2009, a UVI Redevelopment Project started in New Zealand with the objective of considering how best to communicate UVI information via the media (Beckman & Grey 2010). Similar work is also being undertaken in Victoria with regard to UVI evaluation and redevelopment (Makin 2010).

Recommendations

This paper concludes it is timely for Australia and New Zealand to consider a standardised trans-Tasman UVI. Aside from our shared high melanoma incidence rates, reasons for standardisation include:

- the high levels of trans-Tasman migration
- the high levels of trans-Tasman tourism
- the potential for campaigns in each country to promote awareness and understanding in both countries (although a 'redeveloped' UVI would need to be tested and refined for its fit in each country)
- increasing research capacity by harnessing research and evaluation resources and capabilities from both countries
- facilitating international advocacy for a WHO forum to reassess the UVI's effectiveness as a health promotion tool based on Australian and New Zealand experiences as UVI 'guinea pigs' (and the possible need for international resources to assist with ongoing challenges)
- assisting the WHO's goal of a globally standardised UVI, for which standardisation between New Zealand and Australia would be a significant development.

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Developing an effective UV Alert: a qualitative study

Jennifer Makin[1], Billie Bonevski, Flora Tzelepis, Afaf Girgis[2], Irena Brozek[3]

Abstract. The SunSmart UV Alert shows the times each day between which the UV index is forecast to reach 3 or above, when sun protection is recommended. The bell curve design that has been mostly widely used in Australia to communicate the UV Alert is poorly understood. In this study, focus groups explored the use and barriers to the use of the bell curve and alternative UV Alert designs in five outdoor settings. The results point to a need to simplify the design to focus on the times and key message of using sun protection when the UV is 3 and above.

Background

Managing sun exposure is a balancing act between too much (increasing risk of skin cancer) and too little (increasing risk of Vitamin D deficiency) (Kimlin & Tenkate 2007). This requires people to make judgements on when sun protection is required. Since 2005 in Australia, the SunSmart UV Alert shows the times each day between which the UV index is forecast to reach 3 or above, when the WHO and SunSmart recommend sun protection. The UV Alert is available for many locations either in text form and/or as a bell curve graphic in newspapers and on the Bureau of Meteorology website. However, previous research has shown poor understanding and low levels of use of the UV Alert (Makin et al. 2007).

Study aims

This study aimed to explore the use and barriers to the use of the current UV Alert bell curve and potential alternative UV Alert designs in a range of relevant outdoor community settings. Specifically the study aimed to:

1. based on communications theory, develop two designs for dissemination of the UV Alert; and
2. pre-test the design alternatives within a number of settings to determine ease of use, acceptability, attractiveness, comprehension and intention to use.

Methods

Two new designs based on a communications theory checklist were developed by Kent Woodcock Creative Solutions (Figures 1 & 2). In addition, the existing bell curve design (Figure 3) was tested, and in Victoria a previously tested fourth design developed by Trinity (Figure 4) was also tested.

Five focus groups were conducted with adults over 18 in Sydney, NSW, and five in Melbourne, Victoria, in November and December 2008. Two focus groups (one in each state) were conducted with respondents who worked in five selected settings in which responsibility is taken for the sun protection of others: early childhood services, primary schools, secondary schools, outdoor workplaces, and public swimming pools and beaches.

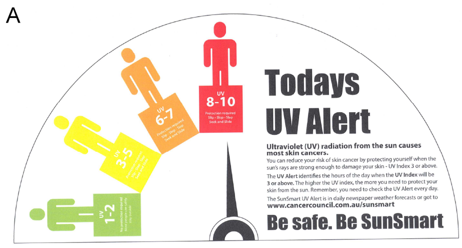

Figure 1. 'Dial' UV Alert design.

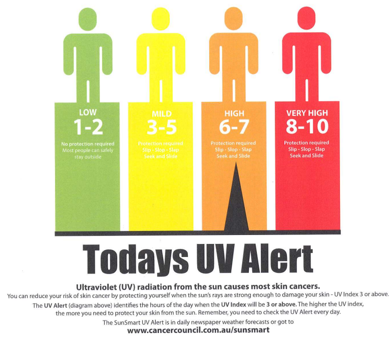

Figure 2. 'Slider' UV Alert design.

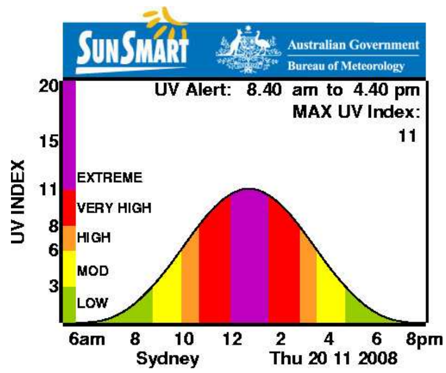

Figure 3. 'Bell curve' UV Alert design.

Figure 4. SunSmart sign.

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The discussion guide covered:

- Sun protection practices in the workplace
- UV knowledge
- Reactions to the designs, and ranking according to which design (i) best conveyed the message “use sun protection between time A and time B, outside these times sun protection is not required”, (ii) was easiest to use, and (iii) was most likely to get people to use sun protection at the appropriate times.
- Attitudes towards the UV Alert message

General results

There was low knowledge regarding UV in terms of peak times, cloud cover, seasonal variation, and vitamin D requirements. Certain beliefs may act as a barrier to using forecast indicators of UV in some settings, including perceptions that the UV is always high (schools), using temperature to prompt behaviour (outdoor workers), and believing sun protection is required all day in summer regardless of UV levels, showing that the more nuanced message of safe times for sun exposure is yet to gain widespread acceptance.

The general consensus was that the SunSmart message has been very effective, and that sun protection policies and practices are well observed in primary schools and early childhood settings, and to a lesser extent in workplaces. There was some concern that making sun protection dependent on the UV Alert may cause some tension with these blanket policies and potentially undermine the sun protection message in these settings.

This suggests that the UV Alert message has limited applicability in early childhood and school settings. For much of the time when a UV Alert is issued, the times encompass the whole school day, reducing the relevance of the UV Alert times. In addition, implementing sun protection for the entire day was considered easier, as varying the sun protection message throughout each day may confuse younger children and create conflict with adolescents. One suggestion was to provide one UV Alert per term, which would show the average pattern of UV levels, as an educational tool and reminder.

Many participants in the outdoor workplace groups reported that their workplaces had sun protection policies; however, implementation and enforcement were reported to be less common than in early childhood and school settings. There was some concern regarding the UV Alert message challenging general sun protection policies; however, these groups were more positive regarding possible application of the message. The swimming pool/beaches group participants were the group most open to the idea of adopting a UV Alert design.

Results for specific designs

The use of the UV Index numbers was not generally seen as useful and was confusing in some contexts; descriptive labels and recommendations/icons for sun protection at each level were preferred.

There were common issues associated with the multiple colours/icons used on the two newly developed designs (‘Dial’ and ‘Slider’) and the bell curve. There was a general perception that different colours/icons should correspond to different levels of sun protection – having the same sun protection recommendations for all colours except green was seen as confusing, inaccurate, and/or not useful. Several participants expressed the view that there would be a tendency to use sun protection only when the Alert showed high/extreme.

From a practical perspective, most participants agreed that it would be difficult to use both alternative designs developed specifically for this study (‘Dial’ and ‘Slider’) due to the increased workload and responsibility of staff required to access information and move the dial/slider several times each day. The absence of any mention of times on the two new designs caused some confusion. Even when used correctly, the designs would only reflect the forecast UV for the present time – they gave no indication to anyone who was not near the display all day of how the UV might vary and when sun protection might be required during the remainder of the day.

The bell curve was recognised by some participants, and favourably received in some groups. However, in general it was poorly understood, and some doubt was expressed across groups regarding its appropriateness for display and use as a daily reminder. Suggestions for improvements included adding sun protection requirements for each UV level, reducing the amount of text/numbers, changing the colour for extreme from purple to red (signifying danger), and adding clear markers on the x axis for the relevant times of day.

The fourth design (‘SunSmart sign’) was tested only in Victoria; without testing in other states it is difficult to draw firm conclusions from the results. However, some groups (outdoor workplace representatives and swimming pool staff) expressed a preference for this design, rating it as more direct than the other designs, easier to implement, and self-explanatory.

What next?

The focus on communicating times for sun protection should be continued and enhanced through future design iterations, noting that in pre-testing of the bell curve design a text-only version was rated as effective but less attractive and credible (Carter 2005). Focusing on the times when the UV is 3 or above comes at the expense of showing variability throughout the day, but simplifies the message. A two-colour version of the Alert should be developed and tested, with colours corresponding to on/off sun protection times. This could also assist in broadening the use of the Alert to focus on ‘safe’ times for exposure for vitamin D production. Further opportunities for communicating the UV Index in real time via mobile technology should be explored.

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Communicating UVR information to the public

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Abstract. The Ultraviolet Index (UVI), while a useful source of sun protection information, has some recognised failings as a communication tool. The Health Sponsorship Council (HSC) is working to improve the messaging, taking into account findings from audience research and media consultation.

NZ UVI – goals and strategy

In New Zealand, since the summer of 2003–04, the UVI has been publicised in the form of a graphic based on the shape of the "fire danger" alert, using colours and numbers consistent with the World Health Organization standards (refer Figure 1), replacing the no longer endorsed 'burn-time' measure.
The goal of the UVI is to "accurately inform New Zealanders of the risk of UVR on a daily basis and the appropriate actions to mitigate those risks".

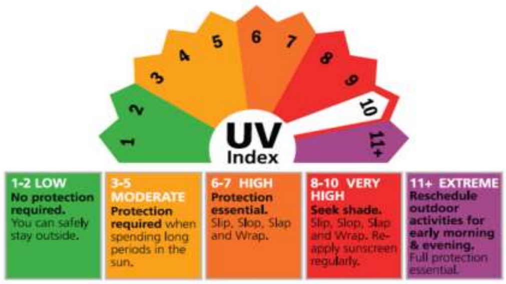

Figure 1. New Zealand Ultraviolet Index, 2003–present.

The HSC is the agency with primary responsibility for promoting the UVI. The HSC has been contracted by the Ministry of Health to deliver a health promotion programme (Sun Safety) that will contribute to a reduction in the proportion of New Zealanders who develop and die from skin cancer. The UVI is an important part of this strategy.

Two key audiences for the UVI are:

- The media that would be presenting the UVI in print, television, and radio.
- The general public who would use the information to protect themselves from harm from the sun. The information presented needs to be timely, relevant, and useful in their daily lives.

UVI communication strategy

HSC contracts the MetService to deliver the UVI to New Zealand media channels. MetService use data from the National Institute of Water and Atmospheric Research (NIWA), which can then be incorporated into news and weather forecasts. Placement channels for the UVI include newspapers, online, on-site notices, text alerts, and television. Television weather forecasts constitute prime media "real estate" – they reach at least one-fifth of New Zealanders every night, are seen as credible sources, enable planning for the next day's activities, and are nominated by audience members as their most commonly accessed source of UVR information.

The HSC/ MetService contract eliminates the need for the media to pay for UVI information – this had previously been a key barrier to media uptake (along with concerns about space and perceived lack of demand by the audience for UVR information).

Media context – issues

By the summer of 2008–09, some national news media (TV One, TV3 and several daily newspapers) stopped broadcasting the UVI. Media groups reported problems with fitting the UVI into the broadcast formats; a perceived lack of interest and understanding due to the lack of change in the UVI over summer; and a lack of regionally specific detail which made the information less relevant and difficult for audience members to apply to their own situation.

HSC research and development

In the years following the launch, research between 2003 and 2006 indicated some increasing awareness of the UVI, but also that it was not necessarily a call to action for those who had seen it. Qualitative research was commissioned in 2008 to build on these findings.

Findings from focus groups showed that, along with general low awareness, the main issues with the UVI were around interpretation. While the UVI was understood at a basic level (i.e., increasing risk), respondents were frequently confused by the detail, and overlaid personal interpretations (e.g., meaning of colours, relevance for own skin type, need to implement behavioural recommendations).

Additional quantitative research supported these findings.

Design issues identified

HSC collated summaries of all available New Zealand and international research with the public on the use and understanding of the UVI. Some of the key modifiable design issues that were identified consistently among studies were used to guide development of an alternative modified tool which would be considered for implementation. Recommended changes to particular elements of the UVI graphic included:

Colour: While the meaning of green (safe to go) and red (danger/stop) were easily understood, the other colours on the UVI produced confusion. The colour scheme needs to be simple and have clear action recommendations.

Scale/ numbers: The meaning of the numbers on the UVI is unclear, and can create confusion.

Timing/ seasonality: The UVI needs to be more clearly applicable to time of day and year, and incorporate the effects of cloud.

Research findings suggested that there was no "one size fits all" method of presenting UVR information – no one UVI design worked on every level for every person surveyed or for each media context.

Possible alternative – audience and media feedback

The HSC commissioned the development of a modified UVI to be considered for future media use. Key elements that were changed before testing included the colour scheme, communication of behavioural recommendations, communication of time, and the overall presentation (Figure 2).

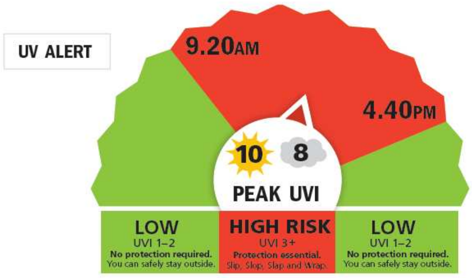

Figure 2. Proposed alternative tool for communicating UVR information, 2009.

This alternative design was tested, along with the current UVI graphic, with a sample of 302 New Zealanders aged 25–54, recruited from an online consumer panel. Key findings included:

- Compared with the original design, respondents demonstrated a significantly higher out-take of recommended sun protection actions needed from the alternative design. A high level of understanding of the UVR risk at different times of day was also demonstrated from the alternative design.
- The time of day at which sun protective behaviour should be taken was rated as the most important of eight UVR messages (43% put it among the top two messages they needed from the UVI).
- Respondents had a strong preference for UVR messages to be daily (rather than seasonal) and regionally specific.

The new design was also shown to media contacts, in meetings arranged by MetService with key personnel from Fairfax Media, APN, TV3 Weather and TVNZ News and Weather. The aim at this point was to solicit ideas and feedback rather than present fixed ideas or decisions.

Overall, there was support from media contacts for the direction taken with the modified version of the UVI.

- The presentation of simple, relevant (regional) information, with greater emphasis on when protection was needed, was supported.
- All media contacts supported the need for clear time indicators and ability to convey change over time (as opposed to the current model which is static, showing peak UVI for the day).
- The clear/ cloudy sky information was not well understood by all.
- Television media contacts felt that the modified version was graphically stronger but would still be incompatible with current weather presentation formats.
- It was acknowledged that the communicating of UVR information was not a case of "one size fits all" and the messaging will need to be designed according to the parameters imposed by the media channels as well as the way in which those channels are used by the public.

Although there is considerable work to do, all media contacts expressed willingness to support the ongoing improvement of both the design and placement of the UVR information.

Future responses

The presentation of UVR information through media channels presents both opportunities and challenges. However, HSC regards the UVI as a valuable part of a wider communications strategy in skin cancer prevention.

HSC will continue to improve the tools used to communicate UVR information, to ensure that it is useful, relevant and enabling to the general public. We intend to continue to work with partners and colleagues and to develop ways to compile, communicate and evaluate UVR information. Future iterations of the UVR communication strategy may incorporate graphic and text based formats, stronger relationships with media, scripted information in weather presentations, ongoing education of presenters, and increased promotion and placement in a variety of media channels.

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Burden of disease associated with low vitamin D status in New Zealand

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Abstract. Low vitamin D status is associated with increased risk of all-cause mortality. The New Zealand population has low vitamin D levels, with marked ethnic variations, and paradoxically high rates of skin cancer. We carried out a comparative risk analysis, to estimate the avoidable disease burden for vitamin D, by comparing the current population distribution of 25-hydroxyvitamin D (25(OH)D) with two counterfactual distributions. The numbers of all deaths avoided by increasing the population mean 25(OH)D level by 10 nmol/L (males 500, females 510), and from increasing it up to 100 nmol/L (males 2430, females 2660), were much higher those from all skin cancers combined attributable to sun exposure (males 260, females 140). The higher mortality burden from low vitamin D status, than from sun-induced skin cancer, has implications for the current policy on sun exposure and vitamin D intake.

Background

Evidence that vitamin D may protect against a wide range of diseases is rapidly increasing. Cohort studies have shown that low blood levels of 25-hydroxyvitamin D (25(OH)D), the metabolite that best reflects vitamin D status, predict increased risk of colorectal cancer (IARC 2008) and cardiovascular disease (Pittas et al. 2010). In addition, a recent meta-analysis of randomised clinical trials has shown that vitamin D supplementation reduces all cause mortality (Autier & Gandini 2007).

Levels of 25(OH)D in the range of 90–100 nmol/L are considered optimal for health (Bischoff-Ferrari et al. 2006). However, mean 25(OH)D levels in New Zealand are much lower than this, being: Pacific Island people 37 nmol/L, Maori 42 nmol/L, and New Zealand European/Others (NZEO) 52 nmol/L (Rockell et al. 2006). These low levels are a paradox, since over 90% of vitamin D is synthesised from sun exposure (Holick 2004), yet the New Zealand population has one of the highest melanoma rates (Sneyd & Cox 2006).

Because of the low vitamin D levels in New Zealand, we decided to estimate the number of deaths that might be avoided by increasing 25(OH)D levels in the general population. We used the World Health Organization Burden of Disease method (Murray 1996), and compared these with the number of deaths from skin cancer caused by sun exposure.

Methods

Full details of the methods and results were described by (Grey et al. 2010). Briefly, we searched the medical literature to identify five cohort studies which compared blood 25(OH)D levels measured at baseline with subsequent risk of all-cause mortality. We then estimated linear regression coefficients from mortality hazard ratios for 25(OH)D categories published in these cohort studies, and calculated a pooled estimate of the relative risk of all-cause mortality per 1 nmol/L increase in blood 25(OH)D (= -0.0042; se = 0.00102).

This regression coefficient was then applied to mortality data for the New Zealand population aged 30 years and over (average of 2002 and 2003), in two counterfactual scenarios using the Burden of Disease comparative risk assessment method (Murray 1996).

This involved comparing the number of deaths under the current distribution of 25(OH)D blood levels in New Zealand, from the 1997 national nutrition survey (Rockell et al. 2006) with the scenario of: (1) increasing mean 25(OH)D levels **by 10 nmol/L**, which is feasible in the short term through public health strategies (e.g., increased sun exposure, nutritional supplements or food fortification); and (2) increasing mean 25(OH)D levels **up to 100 nmol/L**, to provide an estimate of the potential full benefit at 25(OH)D levels associated with optimal health outcomes (Bischoff-Ferrari et al. 2006).

The combined number of deaths from all skin cancers due to excessive sun exposure was estimated by applying standard population attributable fractions previously used for melanoma (90%) and for squamous cell carcinoma and basal cell carcinoma (each 70%) (Lucas et al. 2006).

Results

The proportions of all deaths avoidable from increasing the population mean 25(OH)D by 10 nmol/L (4%), and from increasing it up to 100 nmol/L (males 18%, females 19%), were much lower than the proportions of skin cancer deaths attributed to sun exposure (Figure 1).

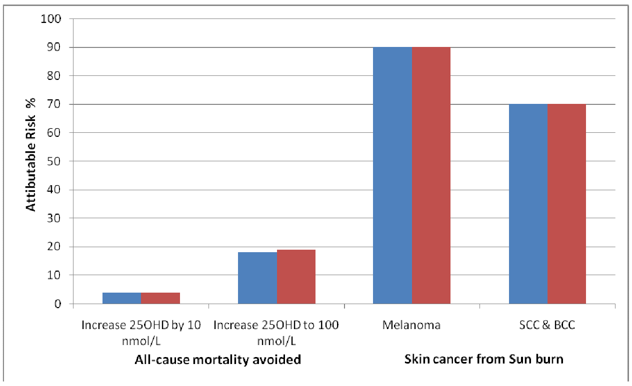

Figure 1. Percent of all deaths avoided by increasing 25(OH)D, and percent of skin cancer deaths attributed to sun exposure (blue, males; red, females).

However, because only a small proportion of all deaths are from skin cancer, the numbers of deaths (from all-causes) avoidable from increasing the population mean 25(OH)D by 10 nmol/L (males 500, females 510), and from increasing it up to 100 nmol/L (males 2430, females 2660), were much higher those from all three skin cancers combined attributable to sun exposure (males 260, females 140) (Figure 2).

The ratio of deaths from comparing all deaths avoidable by increasing population mean 25(OH)D levels by an achievable 10 nmol/L, with skin cancers deaths attributable to sun exposure, is shown in Figure 3, by ethnic group. In all groups, the ratio is well above 1, indicating that public health strategies to increase vitamin D levels have the potential to prevent more deaths than are currently caused by excessive sun exposure. The ratio is much higher among Maori and Pacific Island people, due to a combination of their high all-cause mortality rates and low skin cancer rates, compared to NZEO.

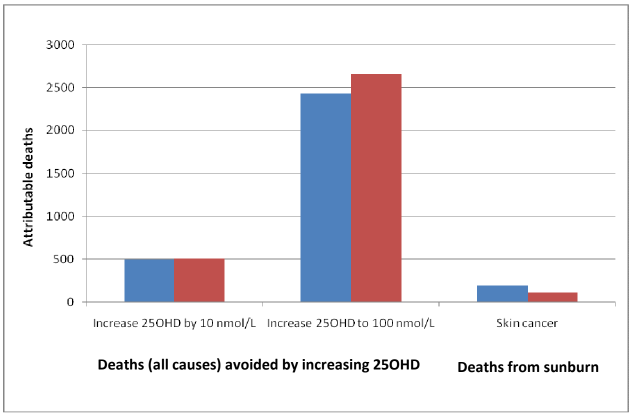

Figure 2. Number of all deaths avoided by increasing 25(OH)D, and number of skin cancer deaths attributed to sun exposure (blue, males; red, females).

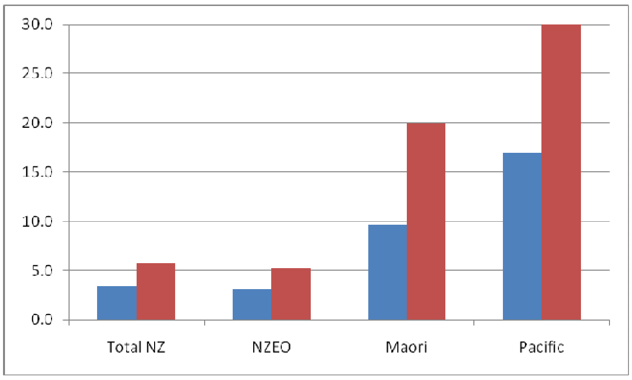

Figure 3. Ratio of deaths avoided by increasing 25(OH)D by 10 nmol/L, to deaths attributable to sun exposure – by ethnicity (blue, males; red, females).

Discussion

Our results suggest that a greater burden of disease could be avoided by increasing the vitamin D status of the general population than that attributable to excessive sun exposure. The potential benefits from increasing vitamin D status are greatest for Pacific Island and Maori peoples; current policies around sun avoidance may not be appropriate for them, as they have both low vitamin D levels and low rates of skin cancer.

The major limitation of our analyses is that we have assumed a causal association between low vitamin D levels and increased risk of all-cause mortality. Large scale clinical trials are needed to confirm the recent meta-analysis of previous studies, primarily carried out to see if vitamin D (with calcium) prevents fractures, which showed a reduction in all-cause mortality (Autier & Gandini 2007). If vitamin D is beneficial in clinical trials, a range of public health strategies could be used to increase population vitamin D levels, including safe sun exposure (without burning), increased availability of vitamin D supplementation and food-fortification.

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The estimated costs – economic and human – of skin cancers to New Zealand

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Abstract. This presentation summarises a report in 2009 to the Cancer Society of New Zealand. The Cancer Society required estimates of the costs to New Zealand of skin cancers, updating a report on this in 2000 (O'Dea 2000). Skin cancers are by far the commonest cancer. They include both melanomas and non-melanoma skin cancers (NMSC), and it is the latter which are very common. Because of their number, the health-care costs of diagnosis and treatment of skin cancers are higher than might have been expected. In fact health-care costs for skin cancer are probably higher than for any other cancer. Fortunately, however, the 'human costs' in terms of premature mortality, especially for NMSCs, are low compared to other cancers, though still substantial enough. This presentation contains summary estimates of the incidence of melanomas and NMSCs, of mortality from these cancers, of their associated health-care costs, and of other economic and human costs. As well, it discusses the uses of such information for assessing the cost-effectiveness of proposed interventions aimed at reducing the incidence of skin cancers.

Background

The earlier report, in 2000, was sparked by Australian estimates (AIHW: Mathers et al. 1999) that health-care costs were higher for skin cancers than for any other cancer. This is quite likely true for New Zealand as well, though not proven, as corresponding estimates for other cancers are not available.

The reason is simply the very large number of non-melanoma skin cancers (NMSCs) occurring each year. Melanomas are much less common. In 2005 there were 18,610 new cancer registrations. Of these, 2017, or about 11 percent, were melanomas. However, NMSCs are not required to be registered. It is estimated, in the work reported here, that about 67,000 new NMSCs occur each year. The consequence is that skin cancers account for over 80 percent of all new cancers each year.

Australian and New Zealand skin cancer rates appear to be comfortably the highest in the world. Presumably high UV intensity is one factor in this.

In 2005 there were 269 deaths from melanoma, and 102 from non-melanoma skin cancers. Together these account for 4.7 percent of total cancer deaths of 7970 in that year. Most skin cancer cases occur among the more elderly. But melanoma has a significantly lower average age of incidence, and mortality, than non-melanoma skin cancers. In 2005 11.9 percent of melanoma deaths were of persons aged under 45, compared with none for non-melanoma skin cancer, and 4.6 percent for all cancer deaths.

Cost estimates

Publicly funded hospital costs (in-patient and day-patient, but not out-patient) are the best documented cost component. These costs are estimated to have been \$26.3 million (excluding GST) in 2006, of which \$3.4 million were for melanomas. To these numbers should be added an approximate additional 10 percent, for privately funded costs.

GP consultation and lab test costs, and other costs, were estimated from a variety of sources, including in particular a data-set of laboratory tests of suspect skin lesions for the Bay of Plenty region, compiled in the late 1990s. Including these estimates, total health-care costs of skin cancer in New Zealand, in 2007–08 prices, are estimated to have been \$57.1 million (excluding GST), of which \$5.7 million was for melanomas, and \$51.4 million NMSCs. For comparison the corresponding estimate in 1998 was a total of \$33.4 million.

Other 'costs' include 'lost production' of \$66 million (of which \$59.3 million for melanomas); and a total of 4741 life-years lost in 2006 to premature mortality, of which melanomas accounted for 3811.

In total then, the estimated 'economic' cost in 2006 was \$123.1 million (in 200–/08 prices); and the 'human cost' was 4741 life-years lost.

Preventive costs

'Preventive' expenditures are an additional cost. These comprise -

- Over \$2 million annually on community preventive measures, by organisations and agencies such as the Cancer Society and the Health Sponsorship Council.
- Sales of protective clothing such as sunhats, though most of this could be regarded as substituting for normal clothing purchases.
- Sales of Sun Screen preparations. Data from AC Nielsen Ltd show supermarket sales of these for the six months to 22 March 2009 to have been \$10.6 million.. Some of this, however, could be intended to avoid the unpleasantness of sunburn as much as consciously reducing skin cancer risk.

The use of 'cost of skin cancer' estimates.

Estimates such as reported here have two main uses

- To gain a feeling for the overall costs of a given disease, helping decide where prevention measures deserve particular attention
- Providing data on disease costs for use in cost-effectiveness evaluations of proposed interventions.

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Comparison between UV irradiances in Christchurch city and the Port Hills

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Abstract. Measurements of the Ultraviolet Index (UVI) in Christchurch city were compared with those made at a nearby site above the city on the Port Hills. After removing effects of differences in altitude and calibration, we found that reductions in UVI due to pollution effects on a clear winter's day were about 40%. The effects increased at larger solar zenith angles.

Introduction

For several years, sun-burning UV has been monitored by IRL at population centres in New Zealand using broad-band International Light Monitors (ILM) (Smith et al. 1997). Instruments are currently located at Auckland, Wellington, Christchurch and Dunedin (another is located at NIWA Lauder, Central Otago, for quality assurance purposes). The sensors are calibrated annually against irradiance standards traceable to NIST that are maintained by IRL. Data from these instruments complement those from NIWA's network of Robertson-Berger (RB) type meters at more remote locations. Data from the latter network are available through NIWA's public Climate Data Base (http://cliflo.niwa.co.nz/), and work is in progress to make the IRL data similarly accessible to the public. In both cases, data are logged at 10 minute intervals, and provided in terms of the UV Index (UVI)[1]. It is well known that Christchurch city suffers from pollution effects associated with winter inversions. Here we investigate the effects of altitude and pollution differences in UVI by comparing measured and calculated values of UVI in the city and at a nearby site on the Port Hills above the inversion layer.

Study method

Measurements of UVI at the Christchurch city site were complemented by an identical set of instrumentation which was set up on the Port Hills, at an altitude higher than the usual inversion layer. Details of the sites are shown in Table 1.

Table 1. Details of the observing sites.

Site	Lat (°S)	Long (°E)	Alt (m)
NRL, Victoria St. Christchurch city	43.53	172.63	5
Gondola Restaurant, Port Hills, Christchurch	43.59	172.71	438

The TUV radiative transfer model (Madronich & Flocke 1995) was used to calculate the expected differences between the two sites under clear sky conditions, taking into effect the differences in altitude, as well as a range of differences in extinctions due to aerosols and trace gases (ozone, SO_2 and NO_2) in the boundary layer. Results are shown in Figure 1. The calculated ratio in UVI between the two sites is relatively small for generally accepted choices of the aerosol parameters. Unlike a previous study comparing UV over a much wider range of altitudes (McKenzie et al. 2001), we expect only a weak dependence on solar zenith angle (SZA) between these two sites.

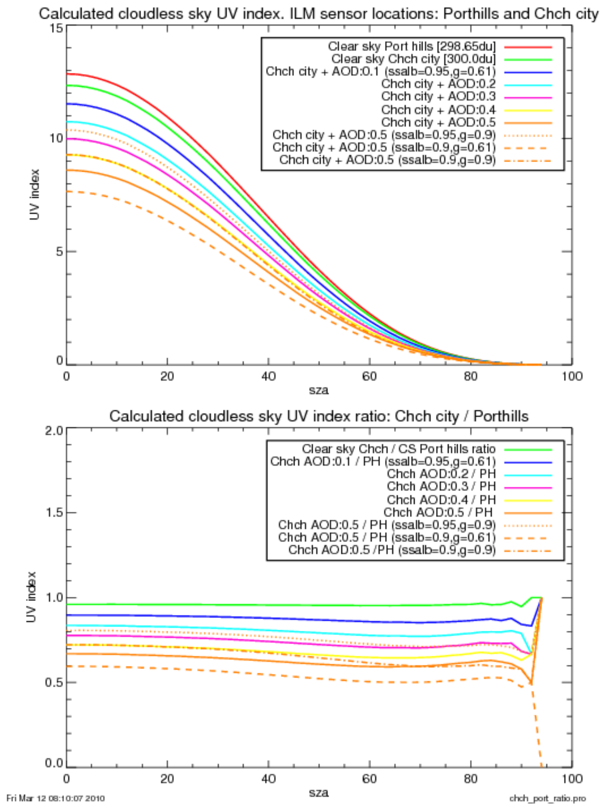

Figure 1. Calculated effects of differences in altitude and pollution effects, plotted as a function of solar zenith angle.

Results

As a quality check, UVI measurements at the two sites were compared with NIWA measurements and with a radiative transfer model for clear skies. Data have been collected from the Port Hills site since December 2003, but unfortunately there are frequent gaps in the earlier years. Data coverage was much better in 2007 and 2008.

[1] UVI = 40 x UV_{Ery}, where the erythemally-weighted UV (UV_{Ery}) is the spectral irradiance in W m^{-2} nm^{-1}, multiplied the erythemal action spectrum (from McKinlay & Diffey 1987).

A subset of the 10 minute data, where all three instruments were operational, was extracted. Ratios of UVI between City and Port Hills sites are plotted in Figure 2. As expected, UVI values in the city are lower than on the Port Hills, especially for larger SZA. There is a wide range in these ratios which arises because at any time one site may be cloudy while the other is clear, and vice versa. For example for small SZA about 50% of the radiation is from direct sunlight, so if the sun is obscured at one site but not the other we would expect the ratios to approach 0.5 or 2.0 respectively. Also, the ratios are plotted as a function of SZA at the city site, and for larger SZA, geographic differences between the two sites become important. However, the observed effect is systematically larger than anticipated by the model, with ratios sometimes being as small. This is probably due to calibration differences.

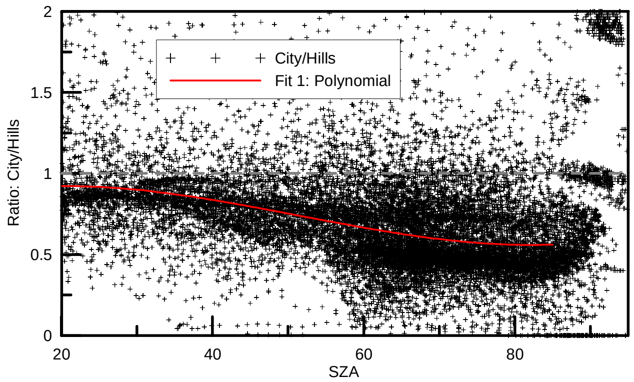

Figure 2. UVI ratio for City/Port Hills, plotted for all coincident data as a function of SZA at the city site. The red line is a polynomial fit.

Corresponding ratios for typical clear summer and winter days are shown in Figure 3. The pollution effect becomes smaller at larger SZA, and is larger in winter than in summer. Apart from occasional outliers possibly caused by shadows, the patterns are similar in the morning and afternoon observations. The minimum ratios are ~0.8 and ~0.5 in summer and winter respectively.

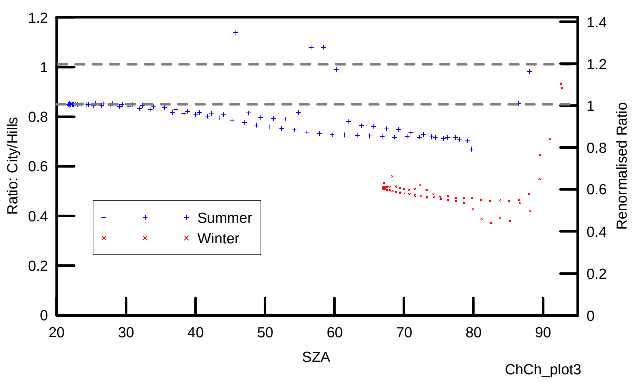

Figure 3. UVI ratio for City/Port Hills on a clear summer day (12 January 2008) and a clear winter's day (18 June 2008).

It is reasonable to assume that pollution effects would be relatively small on the summer's day. Based on that assumption, the lower ratios on the summer day must be due to the combined effects of altitude differences for clean air (< 5%) (McKenzie et al. 2001), differences in surface albedo, more extensive horizon, or calibration uncertainties. After re-normalising the data to unity at low SZA to remove these effects (see right axis of Figure 3), we find that the winter pollution effect remains substantial, with the boundary layer effects reducing UVI values by about 40% (R=0.6) at midday, and by up to 50% (R=0.5) for SZA ~85°.

Conclusions

The observed effects of boundary layer pollution in Christchurch due to extinctions by aerosols and absorptions by trace gases are much larger than predicted by a radiative transfer model using the generally accepted aerosol optical parameters. If these differences are real, then this has important implications for modelling of UV radiative transfer in polluted conditions. And the results could help explain why peak UVI values at unpolluted sites in New Zealand are so much greater than at corresponding latitudes in the more heavily polluted northern hemisphere (McKenzie et al. 2006). There would be better agreement between model and measurement if the single scattering albedo of the aerosols were much lower – more strongly absorbing aerosols. Further work needs to be done to verify the cross-calibration between the two instruments. Spectrally resolved measurements would help identify the causes of any differences.

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Two decades of spectral UV measurements

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Abstract. High-quality spectral UV measurements with NIWA UV spectroradiometer systems have been made for over 20 years in New Zealand and for extended periods at several overseas sites. Any trends due to ozone depletion are small, and are insignificant compared with cloud effects and the large seasonal changes due to changing sun angles. Summertime UV is higher in New Zealand than at comparable latitudes in the northern hemisphere,but peak values are less than at lower latitude sites. In New Zealand, the contrast between summer and winter UV is larger than at all the other sites.

Introduction

Measurements of spectral UV irradiances have been undertaken at Lauder for over 20 years, using instrumentation and data processing techniques that have been developed in house. These instruments represent the state of the art in global monitoring of UV irradiances, and are deployed at several sites within the international Network for the Detection of Atmospheric Composition Change (NDACC). Sample spectra taken at similar solar zenith angle (SZA = 90 – Solar Elevation Angle), and their ratios are shown in Figure 1 (see Table 1 for other parameters).

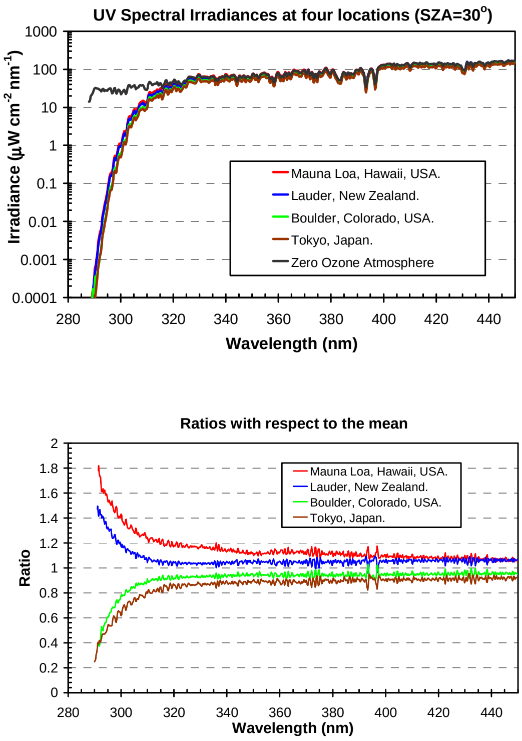

Figure 1. Sample spectra (upper panel) and their ratios (lower panel).

Table 1. Conditions for the four SZA= 30° spectra shown in Figure 1.

Site	Lat (°N)	Long (°E)	Alt (m)	Day of Year	TOZ (DU)	UV_{Ery} (Wm^{-2})
Mauna Loa	19.5	-155.6	3400	216	273	0.284
Lauder	-45.0	169.7	370	028	271	0.247
Boulder	40.0	-105.3	1650	195	306	0.196
Tokyo	35.7	-139.7	57	184	314	0.176

The spectrometer systems have also been used in shorter inter-comparison campaigns in Greece, Greenland, and Antarctica. Although more expensive to maintain than simpler broadband measurement systems, spectrometer systems such as these have several advantages. Firstly, their calibration against irradiance standards is more direct, so overall accuracy is improved. Secondly, spectral signatures can be compared with model calculations to attribute causes of differences. Thirdly, the spectral data can be weighted with any biological weighting function of interest. Here we discuss the temporal and geographic variability of erythemally-weighted UV irradiance (see Figure 2) using long-term data obtained at the sites where NIWA UV spectrometers have been deployed.

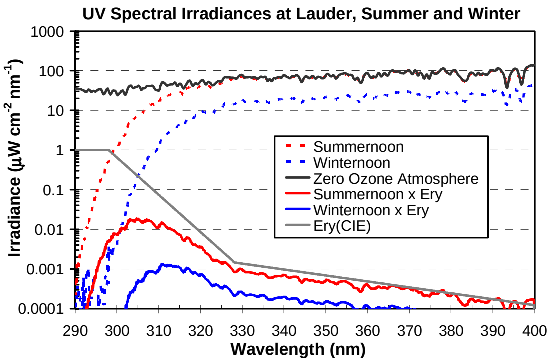

Figure 2. Sample spectra from Lauder, NZ, in summer and winter, compared spectra weighted by the erythemal action spectrum (heavy grey curve). The erythemally-weighted values are 0.284 and 0.0262 Wm^{-2} in summer and winter respectively.

The remainder of the study will focus on erythemally weighted irradiances (i.e., sun-burning irradiances, UV_{Ery}), and derived products including the UV Index which is widely used to disseminate UV information to the public, and Standard Erythemal Dose (1 SED = 100 Jm^{-2} of erythemally-weighted UV), which is a measure of the amount of accumulated sunburning UV radiation incident over a specified time interval. For UV index of 12, one minimum erythemal dose (MED) for fair skinned

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individual (~2 SED) is accumulated in approximately 11 minutes.

Results

Long-term changes in UVI are shown in Figure 3 for sites with records longer than 10 years. At all these sites, long-term changes due to changing atmospheric composition (e.g., ozone depletion) are relatively small. The dominant effects are the seasonal changes due to variations in SZA, and the day-to-day changes due to variations in cloud attenuation. For any given SZA, the UVI tends to be less in spring than in autumn due to seasonal changes in ozone, which has a maximum in spring and a minimum in autumn.

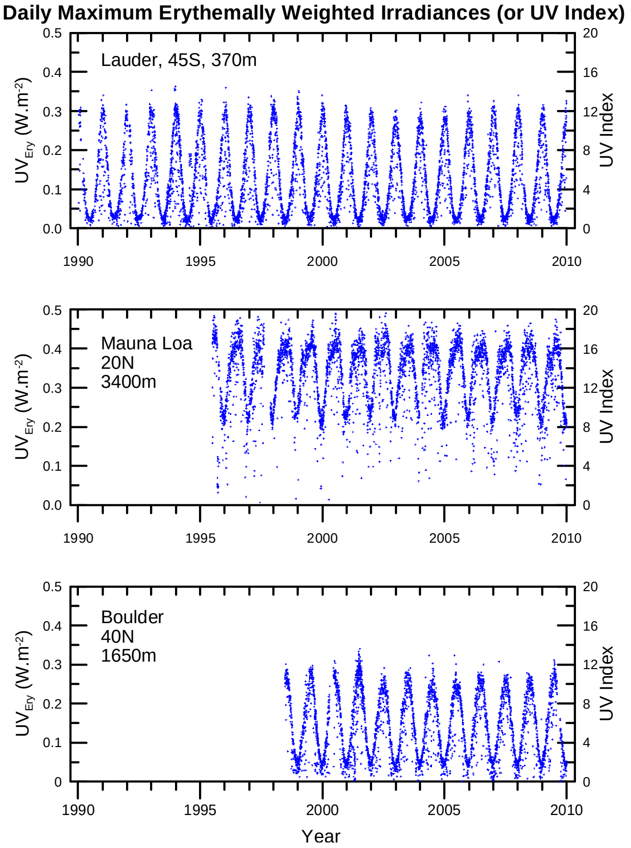

Figure 3. Long-term changes in UV_{Ery} (and UVI) at sites for which more than 10 years of data are available.

Peak UVI values are similar at Lauder and at Boulder, despite the latter being 5° closer to the equator and 1300 m higher. Peak UVI values at the high-altitude equatorial Mauna Loa Observatory in Hawaii are much greater (UVI_{max} = 20).

Seasonal differences in UV at the different sites can also be seen in Figure 3. The main points to note are that at higher latitudes the winter values become very small, whereas at lower latitudes there is much less seasonal variability. As noted previously, peak summer values tend to be greater in the southern hemisphere, due to its cleaner air, its lower ozone and closer sun-Earth separation in summer (McKenzie et al. 2006). In contrast, the winter UV amounts in the southern hemisphere tend to be less than in the northern hemisphere. Consequently, the summer/winter contrast in UV tends to be higher in the southern hemisphere than in the northern hemisphere.

Conclusions

High quality measurements of spectral UV irradiance have been undertaken by NIWA for 20 years at Lauder, New Zealand, and for more than 10 years at Mauna Loa Observatory, Hawaii, and at Boulder, Colorado, USA.

Because of the success of the Montreal Protocol, any long-term trends due to ozone depletion over these measurement periods are small compared with other variabilities. Summertime UV is higher in New Zealand than at comparable latitudes in the northern hemisphere, but peak UVI values are much less than at low latitude, high altitude sites, such as the Altiplano region, where the UVI can exceed 25 (Liley & McKenzie 2006). Of the sites tested, the New Zealand site is the highest latitude. Because of the strong dependence on SZA, this leads to lower wintertime values. The contrast between summer and winter UV shown in Figure 4 is therefore larger there than for the other sites. This large summer/winter contrast in UVI may have deleterious effects on human health.

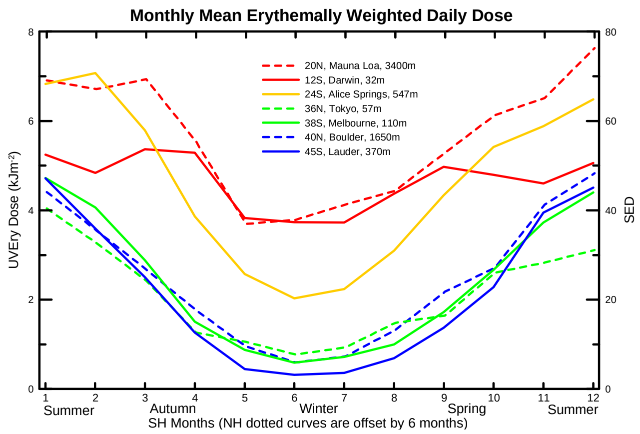

Figure 4. Seasonal change in monthly UV_{Ery} dose at all sites for which more than one year of data are available.

Acknowledgments. The NIWA UV spectrometer systems in USA, Australia, and Japan are owned and operated by NOAA, the Bureau of Meteorology, and the University of Tokyo respectively. We thank the operators at those sites for their assistance.

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Characterisation of AlGaN detectors for UV measurements

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Abstract. Characterisation of commercially available AlGaN Schottky detectors was performed and their spectral response compared with that of the CIE defined erythemal and vitamin-D response curves and older technology detectors. We found these detectors had an excellent 'solar blind' nature and are a good match to these CIE response curves.

Introduction

Since the late 1990s, $Al_xGa_{1-x}N$ detectors have advanced from being the focus of research in the lab to becoming a cheaply manufactured commercial product. Their bandpass shape can be adjusted by varying the concentrations of aluminium (Al) and gallium (Ga) relative to each other. Higher Al concentrations provide a short wavelength cut-off. These detectors have various applications in the measurement of UV irradiance such as in solar measurements, sterilisation processes and communications devices. Five detectors were assessed for their suitability as personal dosimeters. The detectors tested were:

- Two SVTA UV-B sensors – $Al_{26}Ga_{74}N$ concentration.
- One SVTA UV-B sensor with UG11 filter.
- Two GUVB-S11GD UV-B sensors – $Al_{17}Ga_{83}N$ concentration (as used in the dosimeter badges that are currently being used by NIWA).

The AlGaN calibration process

The spectral response of the device under test was compared with that of an MSL reference detector calibrated for spectral response. Each detector was sequentially irradiated with monochromatic light of increasing wavelengths from a McPherson 2035D double monochromator.

A slow response time from the detectors was observed which could be due to the low irradiance monochromatic light used during calibration, but otherwise may still be a problem under sunlight. This slow response was characterised by data-logging the output from the detector during a series of exposures to 300 nm monochromatic light. Additional techniques were applied during spectral response calibration to minimise this slow response:

- Extended the time delay between irradiating the detector and taking measurements from about 5 s to 30 s.
- Applied a -0.015 V bias for some measurements.

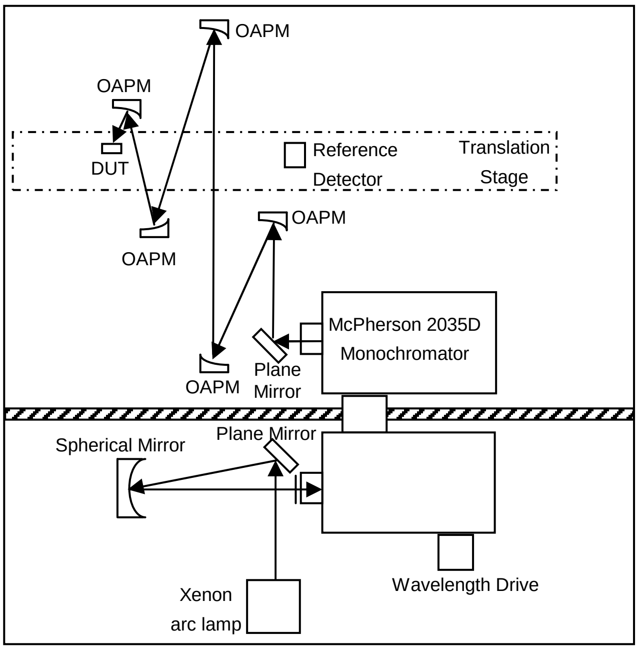

Figure 1. Optical layout of the detector responsivity system.

AlGaN results

Response time measurements

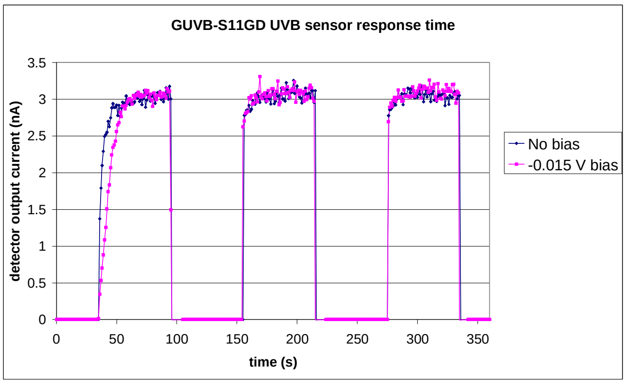

Figure 2. Response time measurements of GUVB-S11GD detector.

After an extended period of time under no UV irradiation, the response time became significantly slower:

- 10–90% rise time of about 10 s with no bias applied.
- 10–90 % rise time of about 15 s with bias applied.

Contrary to expectations, applying a -0.015 V bias actually slowed the initial response time further. On subsequent exposures the response time was much reduced as observed in Figure 2.

Spectral response measurements

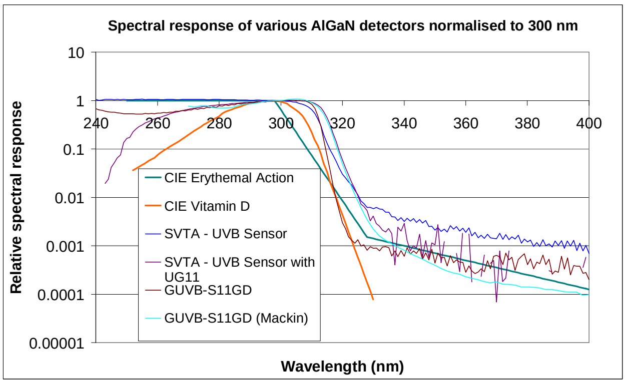

Figure 3. Spectral response of the AlGaN detectors compared with the CIE erythemal and vitamin-D action spectra.

As anticipated, the AlGaN detectors displayed a sharp edge in spectral response, with no response to visible irradiation. However, with the SVTA detectors the edge was steeper than the manufacturer's data suggested and identical detectors showed small changes in edge position. Slow response time was the primary uncertainty factor, giving an overall expanded uncertainty of around 5%.

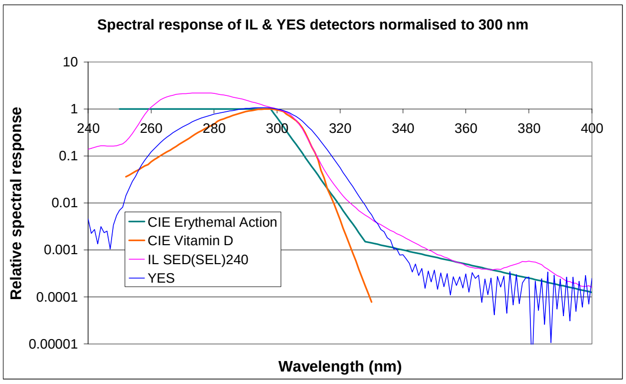

Figure 4. Spectral response of International Light and Yankee Environmental Systems (YES) broadband radiometers as compared with the CIE erythemal and vitamin-D action spectra. Both are intended for solar measurements.

The older vacuum photocell-based International Light detector and fluorescent phosphor and silicon based Yankee are prone to long wavelength leakage and require additional filtering to ensure effective solar blindness. Although common practice, finding a suitable filter-detector combination which matches the response function adequately can be challenging and introduce additional performance issues. For example, the transmittance of interference filters may vary with the angle of incidence of incoming light and some filters are susceptible to fluorescence.

Discussion

For UV measurements, AlGaN detectors are increasingly being used as a better alternative to Si based detectors due to their superior UV response, solar blindness and greater resistance to UV degradation. It is well known that higher Al concentrations produce poorer quality layers in the detector and move the cut-off to shorter wavelengths. With the bulk, low cost manufacturing of this type of detector, a concern is their characteristics may be inconsistent between each batch produced or indeed each detector.

Conclusions

The AlGaN detectors measured have shown they can be tailored to closely match the CIE erythemal and vitamin-D action spectra. However, to have confidence in such devices, it is recommended to perform independent spectral response measurements to verify the general specifications supplied by the manufacturer and perform such measurements on a random sample to verify the variability between detectors.

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Processing and results from RB meter networks in New Zealand

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Abstract. Raw sensor measurements are combined with ozone observations and instrument parameters to calculate the UVI. This is being done for the NIWA network and work is well underway to establish similar processing for the IRL network. The time series of the mean daily accumulated UV show little trend and the greatest spatial difference occurs in wintertime.

Introduction

Observations from the RB meter networks are archived in CLIDB which is New Zealand's nationally significant database for climate data. Access to CLIDB is freely available through the WWW by free subscription to CliFlo (http://cliflo.niwa.co.nz/). The networks were established to understand temporal and geographic variability of UV in New Zealand with NIWA and Industrial Research Ltd (IRL) each running about 6 UV stations. The earliest station was established at Invercargill in 1981, another 6 around 1990 and the rest from 2000. NIWA mainly uses second generation Robertson Berger (R-B) type meters, which are temperature controlled instruments made by Yankee Environmental Systems (YES), while IRL uses International Light Monitors (ILM). All the instruments are calibrated on a regular basis: NIWA instruments by cross calibration against a spectroradiometer at Lauder, and IRL instruments by calibration against FEL lamps at Lower Hutt. The calibration yields factors for applying normalisation, cosine correction and bandpass correction.

Processing

Raw data from both networks are archived in CLIDB and processed NIWA data are available now. NIWA and IRL are currently working towards making processed IRL data available in the near future.

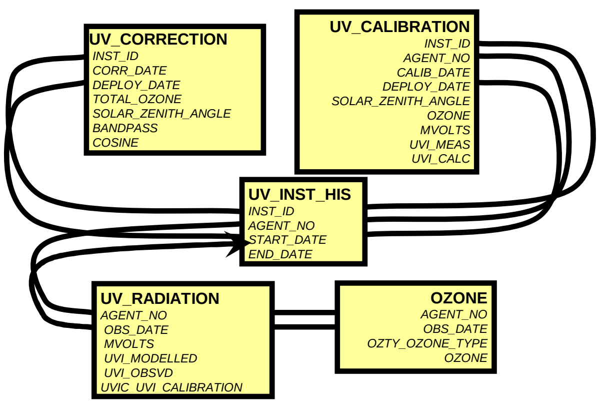

Figure 1. Tables within CLIDB involved in UV archiving and the relationships between the tables.

The convention of Figure 1 of table names in boldface and column names in italic is used in the following text. Ten minute radiometer sensor readings are collected and transferred to **UV_RADIATION**.*MVOLTS* on an hourly or daily basis. Thirty minute modelled UVI and satellite ozone measurements are transferred to **UV_RADIATION**. *UVI_MODELLED* and **OZONE**.*OZONE* once a day and any already calculated **UV_RADIATION**.*UVI_OBSVD* that are contemporary with incoming model/ozone values are removed as they will need recalculating from the incoming new values. High quality daily assimilated ozone measurements are transferred to **OZONE**.*OZONE* about once a year and any contemporary **UV_RADIATION**. *UVI_OBSVD* are removed as above for recalculating. New calibration/bandpass/cosine factors are transferred to **UV_CALIBRATION** and **UV_CORRECTION** about once a year and again, for the period over which the new factors apply, any **UV_RADIATION**.*UVI_OBSVD* are removed so they can be recalculated. Calibration/bandpass/cosine factors apply to individual instruments and the sites where instruments were deployed after being calibrated are also specified in **UV_CALIBRATION**, thus, **UV_INST_HIS**, which holds the history of which instrument was "where at what time", can be populated from **UV_CALIBRATION** and **UV_CORRECTION**.

Once a day **UV_RADIATION** is inspected for entries where *MVOLTS* is present but *UVI_OBSVD* is absent; these values are then calculated from **UV_RADIATION**. *MVOLTS* and *UVI_MODELLED*, ozone observations and the appropriate calibration/bandpass/ cosine factors for the instrument concerned which is found from **UV_INST_HIS**.

Results

The time series of monthly mean daily accumulated UV radiation (kJm^{-2}) for Invercargill, shown in Figure 2, is one of the longest continuous time series of UV available in the world. The data series at the top has been split into seasonal, trend and noise components which are shown in the lower three panels. The bars on the right hand side show the scales for each panel, i.e., the trend has the smallest range and is small compared with the huge seasonal variability (N.B., Missing data have been estimated by the overall mean for the month concerned.)

Time series of monthly mean daily accumulated UV radiation (kJm^{-2}) for all NIWA sites are shown in Figure 3. Only post-1994 is shown in Figure 3 for Invercargill although, as shown in Figure 2, the record started in September 1981. Also the dotted part of the Invercargill trace is for the new instrument. No obvious trends can be seen with summertime values similar at all sites and huge seasonal variation, especially in the south.

For each month of the year the long-term mean daily accumulated UV radiation (kJm^{-2}) divided by Lauder's long-term mean is shown in Figure 4.

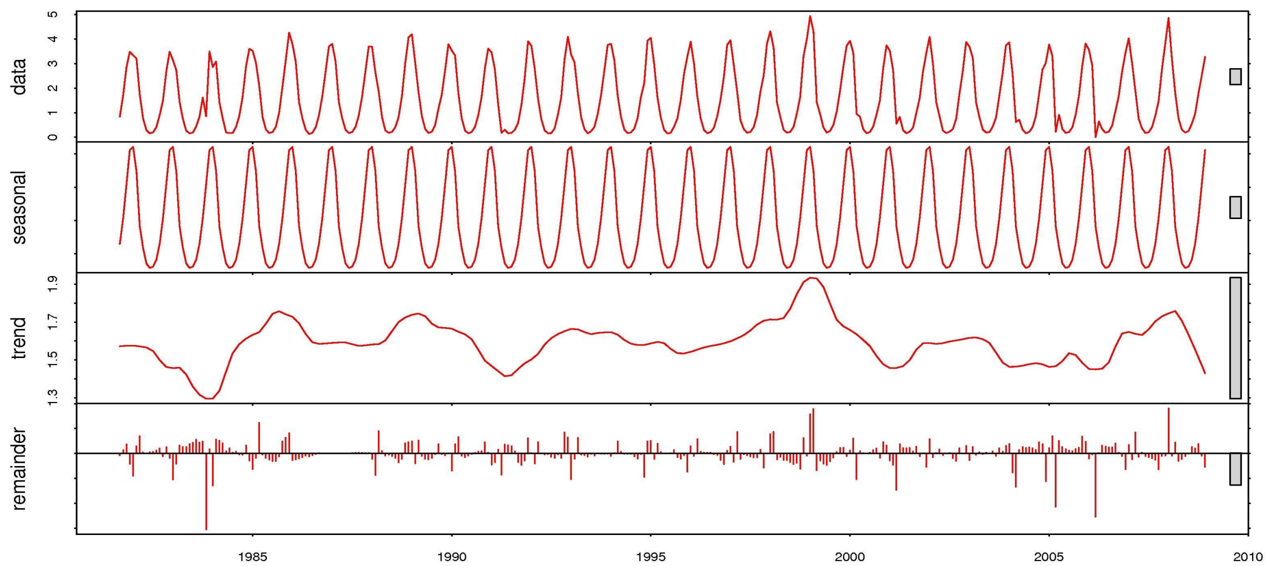

Figure 2. Time series of mean daily accumulated UV radiation (kJm^{-2}) for Invercargill.

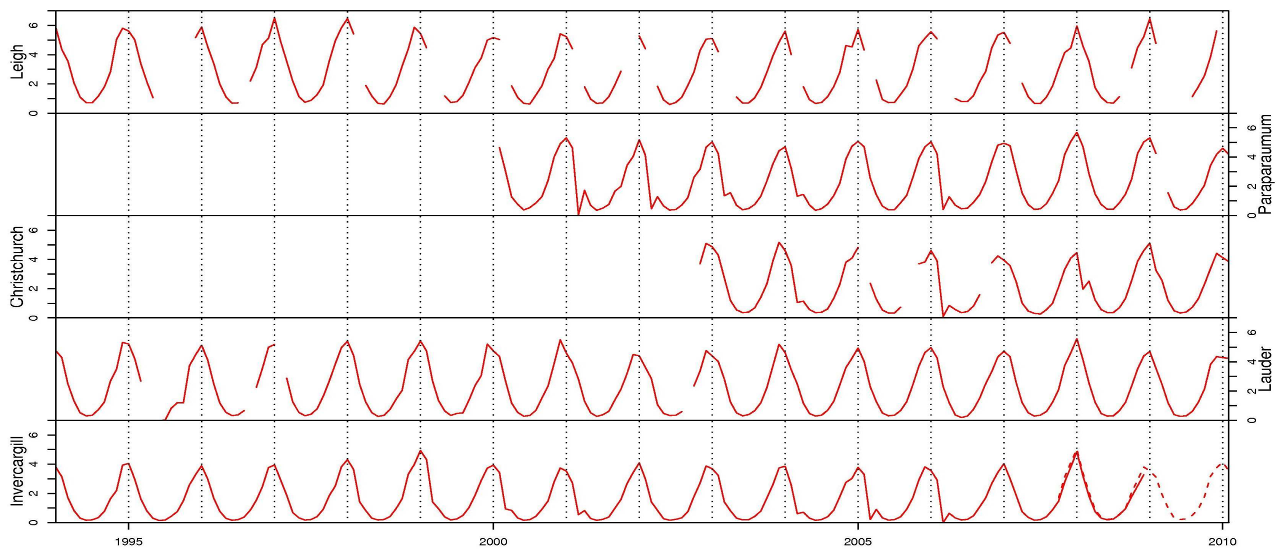

Figure 3. Time series of mean daily accumulated UV radiation (kJm^{-2}) for all NIWA sites.

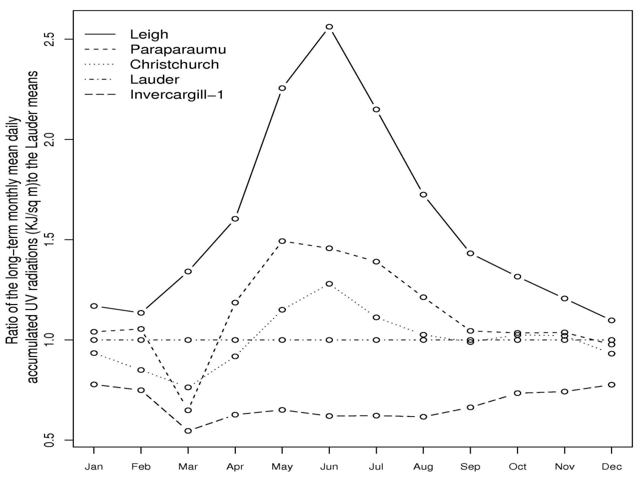

Figure 4. Comparison with the Lauder reference site.

Conclusion

This presentation highlights the huge differences in wintertime UV over New Zealand's latitude range. This may be an important limitation for winter vitamin D production in the south

Analysis of dosimeter badge data

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Abstract. The study of personal UV exposure and vitamin D production using the Allen dosimeter badges required complete data series for all participants, but this was rarely obtained for the 8 or 10 weeks participation. Instead, a range of problems led to gaps in the data that had to be filled. The process required several techniques including heuristic search algorithms, statistical data processing, and supervised and unsupervised machine learning. The three steps in the analysis were: 1) Find and remove false and unreliable measurements, 2) Interpolate available data across areas where measurements were missing, 3) Reduce the data to a usable and presentable format. Ultimately, each participant's data were reduced to 1680 hourly values of average UV, which could then be combined with thrice daily records of clothing worn, daily dietary intake, and subsequent serum 25OHD.

Badge data series

The New Zealand electronic dosimeter badges are described by Allen (2010). In the New Zealand UV-vitamin D study in 2008 and 2009, the badges were worn by 517 participants for 8 or 10 weeks, and set to record every 8 seconds from 06:00 to 22:00. To quantify cumulative UV radiation scaled by skin exposed, the study required complete time series. Instead, a range of badge or operator errors interrupted the individual data series for hours, days, or even whole weeks. Even where data were apparently recorded, there are instances where they are clearly erroneous. Some are much larger than possible for the time of day, supposedly start at the wrong time, or are repeats of earlier data. This could happen because a badge failed to restart, or the data marker that separates new and old data in memory was missing. Static electricity, and poor or bounced battery connections, could also cause data gaps. All of these factors have been considered in updating the badge design (Sherman 2010), but for this study data correction was required.

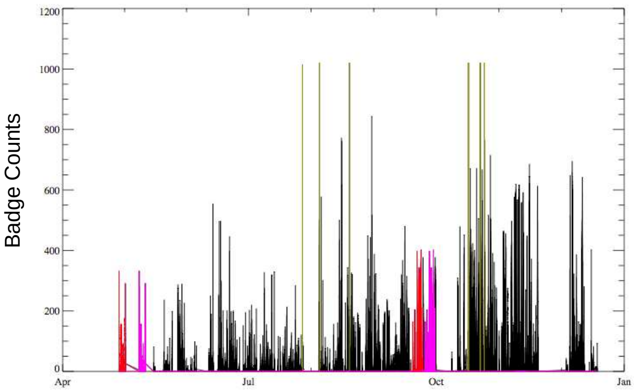

Figure 1. Detecting spikes (green) and repeats in data; first occurrences shown in red, repeats in purple.

All of the corrections described here were automated to work from the raw data, which are unchanged. The first step was to correct any time errors, and remove any time-data pairs that did not correspond to a real measurement. Interviewers' records of visit times and badge issuance were used to resolve instances of concurrent data where a new badge was started for a participant before the old one was stopped.

Heuristic search techniques were used to find repeats, and unsupervised learning algorithms used to scan for areas of malfunction and baseline elevation for each badge. The example in Figure 1 shows spikes and repeated data; the intervals shown in purple are recorded as containing invalid data for that badge and period. Where an elevated baseline was detected, it was subtracted and the data retained.

Participant time series

From data flagged or corrected as above, hourly values for each participant were calculated. For estimated data to fill gaps, a weighted sum of approximating variables was used. Predictor variables for any hour of data included average data values for the person for that hour of the day, average data values for all participants at that hour of the year, average values for that participant during that hour of the week, and average values for the participant over the nearest week in which they had recorded measurements. A single-layer perceptron was utilised to optimise weights, by training on predicting measured values. Evolution of the coefficients is shown in Figure 2.

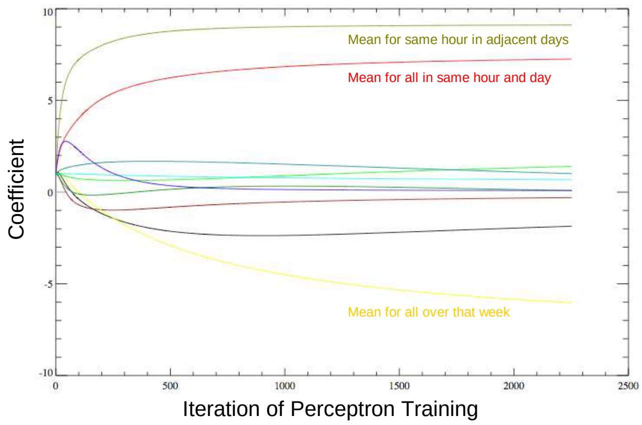

Figure 2. Evolution and stabilisation of the perceptron coefficients with iteration of the training algorithm.

In this instance, weights also gave an indication of the effectiveness of each predictor, though there was collinearity from using both mean and median as separate predictors. The best predictors, consistently across sites and years though coefficients differed, were the mean value for that time of day over the nearest week in which the participant had recorded measurements (9.1 in Figure

2) and the mean for all participants at that time and day (7.3).

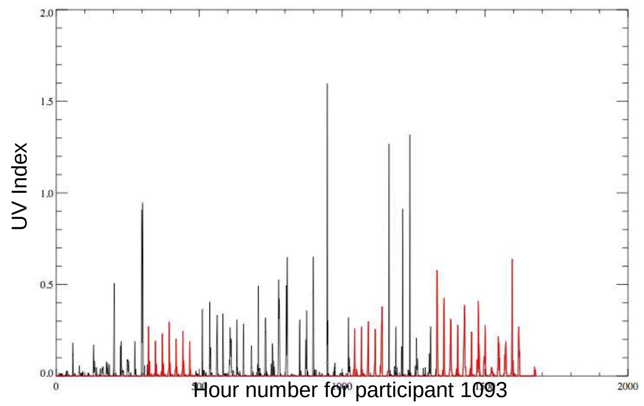

Figure 3. Example of gap filling for one participant.

Figure 3 illustrates how the gap filling completes the hourly data series, though this was an 8-week participant so the last two weeks were not required.

All error detection and correction was automated, as above, for objectivity and repeatability. On the other hand, recognising the types of data error and confirming their resolution required human intervention to review both individual readings and general trends. Figure 4 illustrates one such review, with data from Dunedin to November 2008. The hourly data have been combined into three periods per day (before 11:00, 11:00–16:00, after 16:00) corresponding to the participants' daily logs of clothing worn. In downstream analyses these two datasets are combined to scale the UV received by amount of skin exposed, as the integral of this product is used as a predictor of vitamin D production.

In Figure 4, participants appear as horizontal bars, with coloured bands showing the average UVI experienced over the period. Typically there will be one coloured band per day. The daily total exposure averaged across all participants is shown in red, expressed as Standard Erythemal Doses (SEDs, 1 UVI for 1 hour gives 0.9 SED) on the scale at right. Grey dashed vertical lines are Mondays, highlighting a weekly periodicity for many participants, consistent with spending more time outside in the weekend, especially in the warmer months. Average UV exposures dropped markedly in winter, as expected.

Figure 4 also illustrates other aspects of the study. The upper envelope of the data shows the rate of recruitment of participants, which achieved good uniformity in Dunedin for 2008. The same plot for Auckland (not shown) highlights a slowdown in late winter until more dosimeter badges were made, and the subsequent busy period in spring to achieve target numbers. In 2009, both Dunedin and Auckland achieved uniform recruitment.

Other measures of the UV exposure have also been derived from the badge data. From a knowledge of the UV irradiance spectrum for given solar zenith angle and ozone amount, the nearly erythemal response of the badges can be converted to CIE or other vitamin D action spectra.

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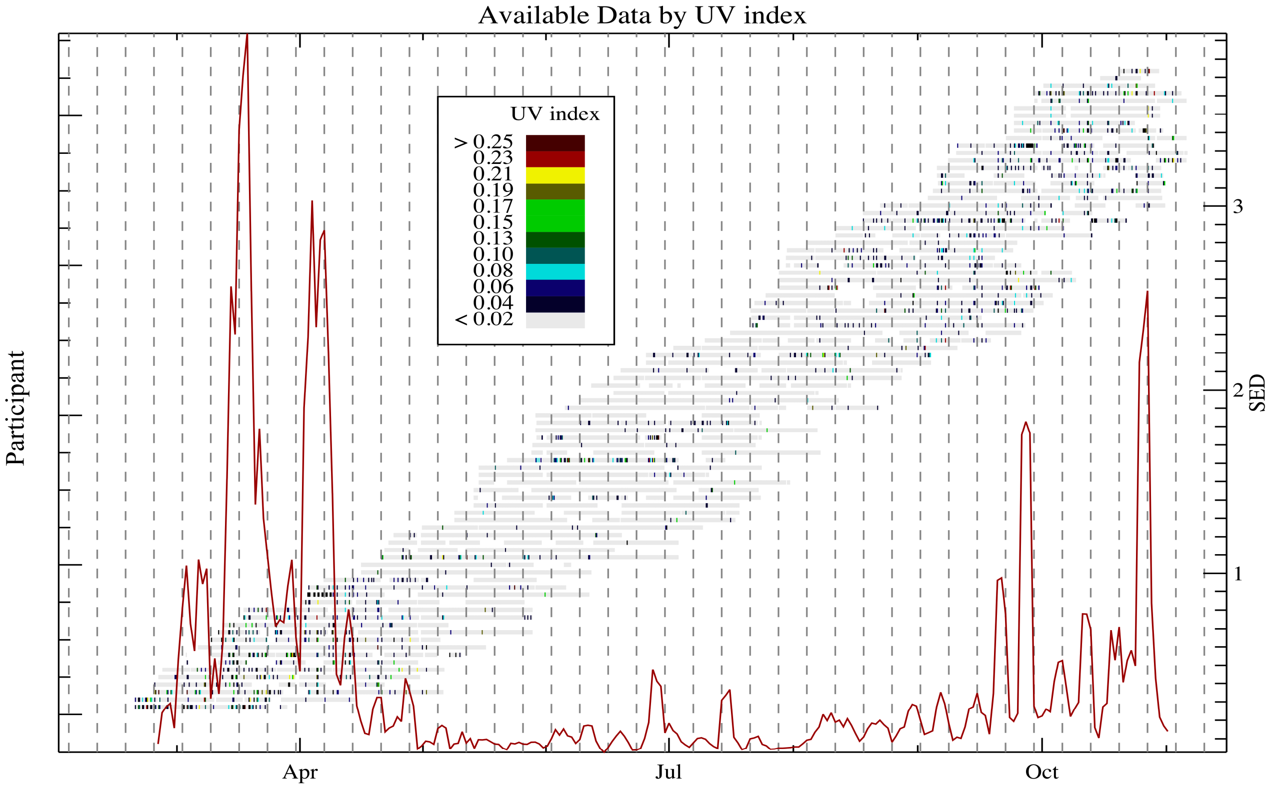

Figure 4. Data for Dunedin 2008, with participants as horizontal bars in three periods per day, gaps for missing data, and colours for average UVI. Average received SEDs for the day are in red, and grey dashed vertical lines are Mondays.

Dermatological lamps as a source of vitamin D

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Abstract. Dermatological lamps emitting UV-B or UV-A radiation have been used at our surgery in the treatments of a wide variety of skin conditions. The use of UVR in the treatment of skin cancer, autoimmune and chronic inflammatory diseases of the skin is discussed. Additionally, the equipment has been used, as part of research in collaboration with the University of Auckland, to better understand the relationships between exposure to UV radiation and health effects such as heart disease and vitamin D status. Some recent results are highlighted.

Clinical trial

A trial comparing the effects of narrowband UV-B or UV-A on blood pressure and serum vitamin D levels was performed between 2006 and 2007 in the winter months; 123 patients who all had levels under 50 nmol/litre were treated.. A total of 24 exposures were given over a 12 week period. Serum Vitamin D increased from 43.2 to 92.6 in the UV-B arm and from 45.5 to 64.9 in the UV-A arm of the study. The latter group was designed to be the placebo arm. This was significant (the P value being less than 0.0001.). It indicates that patients undergoing phototherapy have significant vitamin D increases. Whether this is related to therapeutic response is currently unknown, although it may well be so. The blood pressure did not change. Results of these studies have been reported elsewhere (Wishart & Scragg 2009, Scragg et al. 2010).Other results coming from these clinical trials include independent measurements of the spectral output from these chambers (Johnston & McKenzie 2010), and an assessment relating UV exposures in the UV-A and UV-B chambers to changes in vitamin D status among a range of skin types (McKenzie et al. 2010).

Photodynamic therapy

Metvix is the antineoplastic agent we use when performing photodynamic therapy. The active substance is methyl aminolevulinate (as hydrochloride). We use a red LED light which has an average wavelength of 630 nm and requires a total dose of 37J/cm^2 to activate the cream. It is used to treat actinic keratoses on the face and the scalp. It can be used to treat primary superficial and nodular forms of basal cell carcinoma (BCC) when pPhotodynamic therapy also for mycosis fungoides (T Cell lymphoma) and we have also treated lesions on the face of a patient with lupus pernio.

Treatment consists of application of the cream, followed by light exposure (photodynamic therapy) three hours later. The lesions absorb the methyl aminolevulinate from the cream. By subsequent exposure to light, the lesion cells are destroyed while normal skin will not be affected.

At three hours, if the room is darkened and a Wood's light held to the area of the lesion, there will be an uptake by the cancer cells and this is demonstrated as pink fluorescence before light exposure (Figure 1). Fluorescence is quenched by LED.

Figure 1. Pink fluorescence in cancer cells can be seen using a Wood's before exposure from a red LED.

Treatment of vitiligo

Here we discuss a case study of vitiligo treatment with a variety of wavelengths of light.

Before 2000 the patient started intermittent treatment PUVA Sol in India, Egypt and Germany. This was followed by treatment in India from 2000 to 2003 using PUVA, starting with oxsoralen pills and then changing over to topical psoralen.

Treatments involving exposures to light began in Dunedin in 2004. For one year, PUVA treatments were administered – 46 exposures up to 3.5 Joules, giving a total of 143 J/cm2.

In March 2005 the patient started narrowband UV-B treatment at Dr John Wishart's clinic. In total she received 29 treatments of narrowband UVB

She then started using oxsoralen (20 mg) and exposures in whole body. She received 8 exposures to UV-A bed. She then changed to oxsoralen gel and, starting at 0.2J with gradual weekly increases, she received a further 39 whole body UV-A exposures.

Then she changed to TUV (high dose targeted phototherapy) of UV-B to the left and right side face, gel to left side face only and then UV-A to left superimposed on top of a UV-B dose. In total she received 24 exposures.

Then she received UV-A treatment only on both sides with Gel 48 exposures up to 11.7.2007.

Finally, the patient received 102 further treatments of TUV – using UV-A radiation. The photographs in Figure 2 show her response to these final series of treatments between 11 July 2007 and 25 March 2010.

Figure 2. Images of the patient before, during and after 102 treatments of high dose targeted UV-A phototherapy.

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Understanding UV reflection in the urban environment

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Abstract. Outdoor workers in Australia are exposed to very high ambient levels of ultraviolet (UV) radiation. Studies have shown that up to 90% of outdoor workers experienced UV exposures in excess of the occupational UVR exposure standard. Surfaces that reflect UV have been shown to significantly affect UV exposures and vary with solar zenith angles (SZA) and orientation of the surface and surface type.

This investigation shows that seasonal variation is just as important to UV exposures affected by reflected UV radiation. In fact, UV exposures received in cooler seasons appear to be affected more by reflected UV than in warmer seasons, despite higher levels of global UV. Such high ambient UV levels are proposed as the reason for the disparity between UV exposures measured in spring and autumn, due to proportions of direct and diffuse UV radiation, despite the use of a UV reflector that has a high UV reflectivity in comparison to natural surfaces (at least 20% in the UVB waveband).

Calculating reflective capacities

This study was carried out using polysulphone dosimeters (to approximate UV exposure) attached to manikins placed in a variety of situations. A manikin was placed near a UV reflective wall, a second manikin was placed near a non-reflective wall and a third manikin placed in the open. Dosimeters were positioned at the same place on each head. The manikins were placed 0.5 m from the wall, at the point of the shoulder, approximating arm length. The dosimeters were replaced after each hour of exposure to determine the hourly exposures over an entire day. The dosimeters were calibrated to a spectroradiometer (model DTM 300, Bentham Instruments, Reading, UK) and weighted against the erythemal action spectrum. The final results in this study concentrate only on the dosimeters located on the face. The spectral analysis was carried out with a USB 4000 Plug-and-Play spectrometer (Ocean Optics Inc., USA). This was also calibrated against the Bentham spectroradiometer. The walls used in the dosimeter study included zinc aluminium coated steel in trapezoidal shape (reflective surface) and black felt covered steel in trapezoidal shape (non-reflective surface). The experiments were carried out at the University of Southern Queensland, Toowoomba, in Queensland, Australia.

Observations

The data collected show that during late autumn the presence of a nearby reflective wall can increase personal UV exposures to the face by nearly a third (Figure 1a). However, when the same experiment was carried out during late spring of the same year, the effect of the reflective wall on personal UV exposure appears to cause only slightly higher UV exposures with the exception of 10 am to 11 am (Figure 1b) compared to measurements obtained with no wall nearby in the mornings. Afternoons show low to no increase for UV exposures in spring.

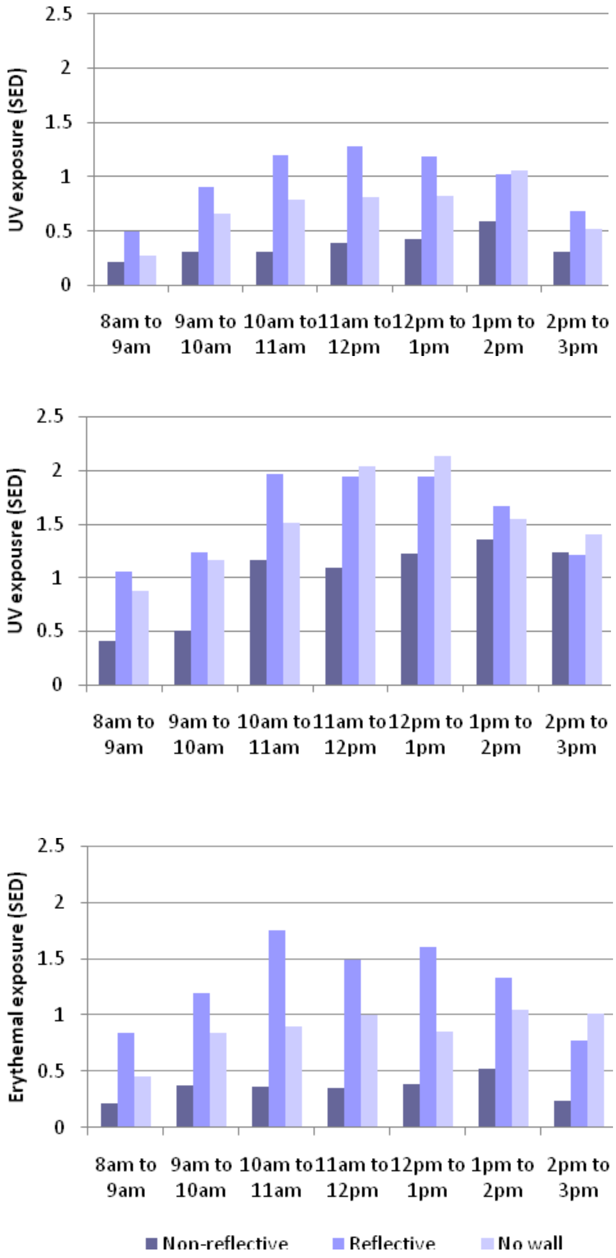

Figure 1. From top: average facial erythemal exposure (SED) for three exposure types (a) comparing walls in autumn 2008 (b) comparing walls in spring 2008 (c) comparing corners in autumn 2009.

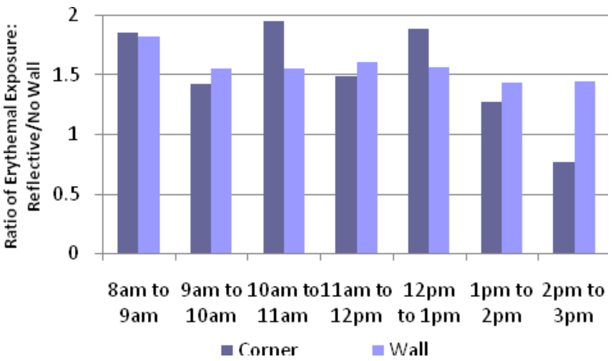

Figure 2. Comparison of relative effectiveness of increasing erythemal exposure due to a wall or corner.

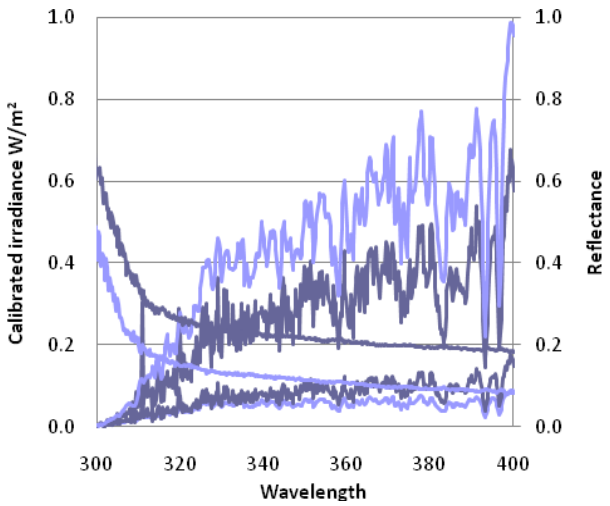

Figure 3. Comparison between spring and autumn data for 2008. Light shade: spring 2008; dark shade: autumn 2008. From top the paired lines are: global spectral UV irradiance, reflectance ratio and spectral reflected UV irradiance.

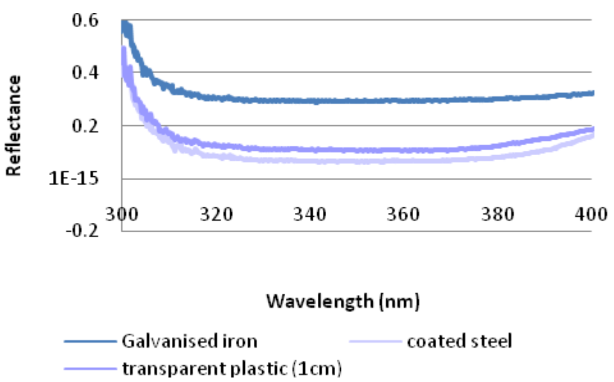

Figure 4. Other UV reflective surfaces that may increase UV exposure.

An investigation into the effect of two walls (positioned in a corner) shows that autumn measurements in 2009 also increase overall UV exposure (Figure 1c). The relative value of UV exposure due to a reflective wall nearby is still about a third higher than when no wall is nearby. Figure 2 confirms this, showing little relative variation between wall or corner influence to UV exposures compared to no wall present nearby. Despite higher ambient UV in spring, UV exposures incurred (averaged over the day) do not appear to have significantly increased due to the presence of a reflective wall, unlike the overall UV exposure incurred during autumn.

Figure 3 shows a sample of spectral UV irradiance data measured at noon, with higher global UV measured in spring compared to autumn, and the reflected UV from the wall remaining approximately the same for both seasons. The higher global spectral UV is due to smaller SZA in spring. It appears that while higher spectral UV irradiance is present, the reflectance capacity of the UV reflective surface remains relatively constant from season to season. The most logical explanation for this is that UV reflective surfaces must reflect mostly direct UV radiation, with little to no impact on diffuse UV radiation. The proportion of direct to diffuse UV radiation changes from season to season, with direct UV radiation levels changing less significantly than diffuse UV radiation. Figure 4 shows other examples of UV reflective surfaces, indicating that other higher reflecting UV surfaces may also display this behaviour.

Conclusion

Outdoor workers should be advised to take the same safety precautions working near UV reflective materials in cooler seasons as they would working outdoors in warmer seasons, particularly when thermal considerations may encourage them to remain in sunny areas. Workers should also be advised that working near UV reflective walls has the same effect as working near UV reflective corners and should again take appropriate precautions against excessive UV exposure when working in these conditions.

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Neonatal exposure to solar simulated ultraviolet radiation leads to deviation of immune development

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Abstract. Exposure to ultraviolet radiation (UVR) during childhood reduces the likelihood of developing auto-immune disease, but increases the risk of developing melanoma. As immune suppression is likely to contribute to both of these alterations, we propose that exposure to UVR during the neonatal period modifies development of the immune system. To test this hypothesis, neonatal mice were exposed to a single erythemal dose of solar simulated UVR at 3 days of age. At 8 weeks post-exposure the contact hypersensitivity response to oxazalone was significantly reduced in the neonatally irradiated mice. Analysis of the lymph nodes of such mice revealed an increase in the percentage of T regulatory cells. Furthermore, during the challenge phase of the contact hypersensitivity response, the number of T regulatory cells within the medullary cord region of lymph nodes was significantly increased, suggesting that these cells are responsible for the suppressed response in neonatally irradiated mice. When an equivalent number of T regulatory cells was isolated from irradiated or control mice, 8 weeks after neonatal irradiation, the suppression was not transferred to naïve mice to a greater extent by the cells from the irradiated mice. As such, we propose that exposure to UVR during the neonatal period leads to a deviation of immune development, leading to suppressed immunity which is not due to the induction of T regulatory cells.

Introduction

Childhood exposure to burning doses of sunlight increases the risk of developing melanoma, the most lethal form of skin cancer. In contrast, low dose childhood exposure may protect against the development of autoimmune diseases including multiple sclerosis and rheumatoid arthritis. These findings imply that childhood exposure to sunlight may modulate the immune response, most likely through the induction of immunosuppression. In support of this, exposure to various other agents, including pathogens, chemicals and allergens, in early life have a major impact in directing development of the immune response. It is likely that sunlight is another of these agents. As such, we analysed changes in the skin immune system following neonatal exposure to solar simulated ultraviolet radiation (ssUVR) with the aim of identifying alterations that may play a role in the development of immunosuppression.

Methods

To test this hypothesis, neonatal BALB/c mice were exposed to a single dose of solar simulated UVR at 3 days of age from Cleo natural lamps. Doses used ranged from two to four erythemal doses. Changes in the skin immune system, including the contact hypersensitivity response and the proportions of immune cells in skin draining lymph nodes, were assessed in mice when they reached adulthood, 8 weeks following neonatal irradiation.

Contact hypersensitivity and tolerance

Neonatal mice were irradiated and 8 weeks later, the contact hypersensitivity response to oxazalone was assessed. Increase in ear thickness following antigen challenge was measured using a spring-loaded micrometer. Neonatally-irradiated mice had a significantly reduced contact hypersensitivity response compared to their unirradiated counterparts (Figure 1). Additional experiments showed that when antigen sensitisation occurred during the neonatal period at 3 days post-irradiation, followed by challenge in adult life, there was a greater reduction in the contact hypersensitivity response, reflecting increased tolerance induction (Figure 2).

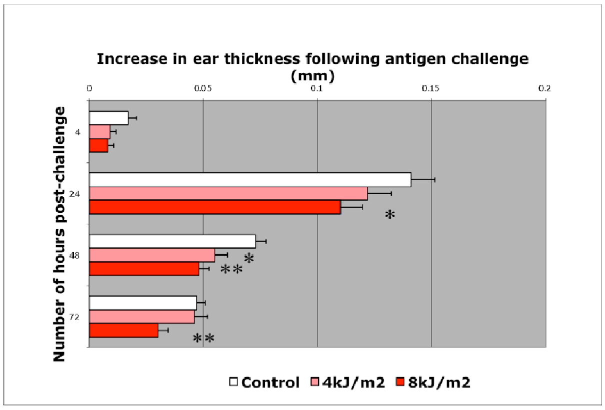

Figure 1. Contact hypersensitivity at 8 weeks post-neonatal irradiation. The response is significantly suppressed in mice exposed to ultraviolet radiation than their control counterparts. (* $p<0.05$)

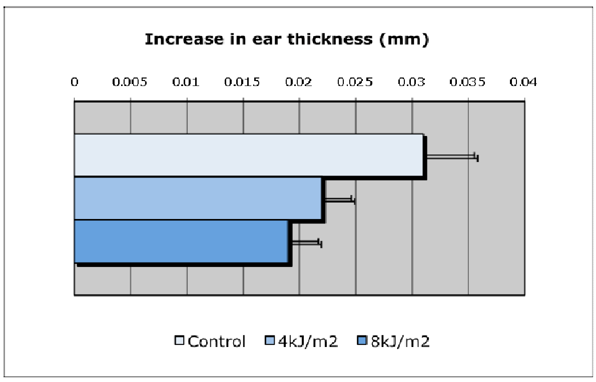

Figure 2. Neonatal tolerance induction. The level of tolerance is increased (and therefore ear swelling decreased) in mice that were exposed to ultraviolet radiation as neonates.

Lymph node resident cells

Mice were irradiated as neonates and 8 weeks later the skin draining lymph nodes and the spleens were removed and analysed using flow cytometry. A slight increase in T regulatory cells was observed in irradiated compared to control mice (Figure 3), as was a decrease in the level of expression of IgD by B cells in the draining lymph nodes. There were no differences in the proportions of other lymph node cells. In addition, cell populations in the spleen were unaffected, hence a local alteration in immune development is likely.

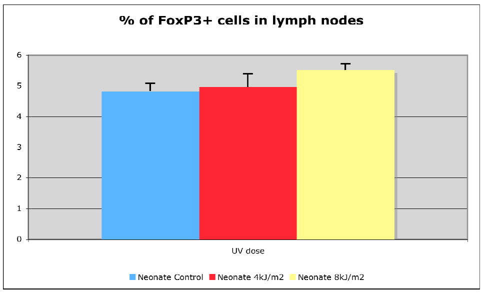

Figure 3. T regulatory cells. When the percentage of T regulatory cells was assessed using flow cytometry, a dose-dependent increase was observed at 8 weeks post-neonatal irradiation. y-axis represents percentage of lymph node cells expressing FoxP3.

When assessed *in vitro*, there was a similar capacity for proliferation by lymph node cells obtained from neonatally-irradiated compared to control mice. Despite this, there was an altered cytokine profile, with lymph node cells from irradiated mice producing more IL-10 and IFN-γ than cells from control mice (Figure 4).

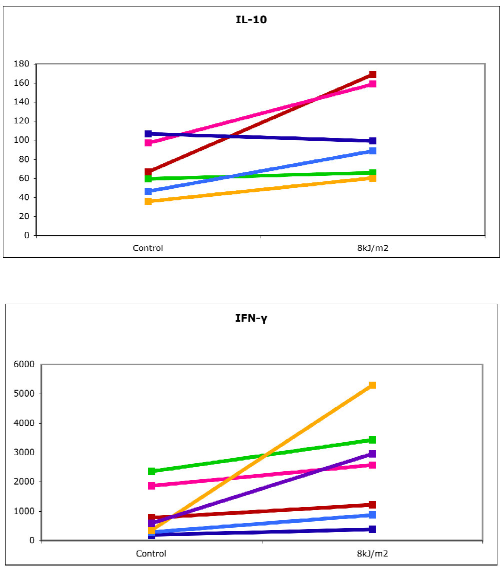

Figure 4. Cytokine production by lymph node cells. Cytokine production was measured on culture supernatants by ELISA. Each line represents a single experiment and the y-axis represents cytokine concentration in pg/mL. The production of both IL-10 and IFN-γ were increased.

Transfer of suppression

As the number of T regulatory cells and production of IL-10 was increased, it could be suggested that T regulatory cells were responsible for the observed immunosuppression. When assessed *in vitro* by isolating T regulatory cells and adding them to a CD3/CD28 stimulated lymphocyte culture, no suppression was observed (Figure 5). When assessed *in vivo* (by isolating T regulatory cells, transferring them into naïve mice, and assessing contact hypersensitivity), suppression was also not observed (results not shown). Furthermore, transfer of whole lymph node cell suspensions could not transfer the observed suppression (data not shown).

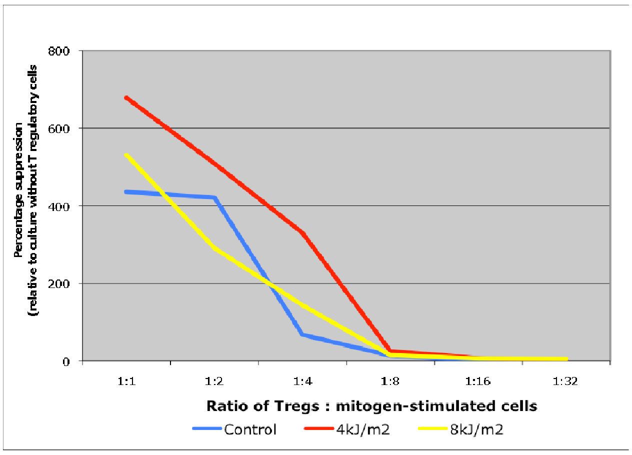

Figure 5. *In vitro* suppression. When T regulatory cells were isolated from mice and co-cultured with mitogen stimulated lymphocytes, there was no difference in suppression from T regulatory cells obtained from irradiated compared to unirradiated mice. (Differences were not statistically different.)

Conclusion

Neonatal exposure to ultraviolet radiation leads to long lasting suppression of the immune response. At the time this suppression is observed, an alteration in the lymph node cell profile can be seen, as well as in the cytokine profile these cells produce. This is not associated with suppression of proliferation. Furthermore, this suppression does not appear to be due only to the induction of a suppressive cell population within the skin draining lymph nodes. We propose that neonatal exposure to ultraviolet radiation alters development of the immune response, thereby altering the contact hypersensitivity response in adult life. This is different from the early suppressive response following adult exposure to ultraviolet radiation which tends to be due to the induction of a single or multiple populations of suppressive cells.

Estimation of the benefits of raising mean serum 25-hydroxyvitamin D levels to 100-115 nmol/L world wide

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Abstract. The understanding of the health benefits of solar ultraviolet B (UVB) irradiance and vitamin D is expanding rapidly based on a combination of ecological, observational, cross-sectional, laboratory, and clinical studies and randomised controlled trials (RCTs). The strongest evidence for non-calcemic effects is for many types of cancer and several types of infectious and autoimmune diseases. Encouraging and generally consistent findings have been reported for cardiovascular, metabolic, and neurological diseases and congestive heart failure. The serum level for optimal health has been reported to be 100–150 nmol/L (40–60 ng/mL) in observational studies, meta-analyses of such studies, and RCTs. The benefits of raising mean population serum 25-hydroxyvitamin D (25(OH)D) levels from 40 to 63 nmol/L to 100–113 nmol/L can be estimated based on dose-response relations for various diseases and incidence or mortality rates for these diseases. This abstract presents an overview of the approach and representative findings for several countries.

Basis for 100–113 nmol/L

Various ecological and observational studies and randomised controlled trials provide evidence for using 100–113 nmol/L as the target level for benefits. One reason is that the mean serum 25(OH)D level of the highest quantile in observational studies is near there. Some examples:

Meta-analyses of cardiovascular disease and diabetes incidence (Parker 2010).

Randomised controlled trial of vitamin D supplementation and type A influenza incidence (Urashima et al. 2010).

Seventeen vitamin D-sensitive cancers with strong support**,** primarily from ecological studies, with some observational studies, for incidence and/or mortality:

Blood: Hodgkin's and non-Hodgkin's lymphoma;
Female: breast, endometrial, ovarian, vulvar;
Gastrointestinal: colon, esophageal, gallbladder, gastric, pancreatic, rectal;
Male: prostate;
Urinary: bladder, renal;
Miscellaneous: lung, melanoma.

Evidence for cancer

The evidence for a beneficial role of UVB and vitamin D in reducing the risk of cancer and the dose-response relation is based on numerous studies, with ecological and observational studies covering many types of cancer (Giovannucci et al. 2006, Grant & Garland 2006, Grant 2007).

The serum 25(OH)D level-cancer incidence relation has been developed for breast cancer using five prospective studies referenced to prediagnostic serum 25(OH)D levels (Abbas et al. 2008, 2009, Bertone-Johnson et al. 2005, Crew et al. 2009, Freedman et al. 2008, Lowe et al. 2005). The data for mean serum 25(OH)D levels for the quantiles in the study from 22 to 153 nmol/L were fitted to a power law with the equation odds ratio

(OR) = $7.41\text{x}(25(\text{OH})\text{D})^{-0.603}$ (p=0.91)

A similar relation was found for colorectal cancer:

OR = $3.95\text{x}(25(\text{OH})\text{D})^{-0.541}$ (p=0.77)

Evidence for cardiovascular disease

The evidence of a beneficial effect of vitamin D in reducing the risk of cardiovascular disease is primarily from prospective observational studies. Using data from six recent studies (Dobnig 2008, Ginde 2009, Giovannucci 2008, Kilkkinen 2009, Melamed 2008, Semba 2009), a power law fitted to the data yields the finding

hazard ratio = $5.22\text{x}(25(\text{OH})\text{D})^{-0.425}$ (p=0.87) (Grant, unpublished).

Evidence for all-cause mortality rate

The evidence of a beneficial effect of vitamin D in reducing the risk of cardiovascular disease is primarily from prospective observational studies. Using data from four recent studies (Dobnig 2008, Melamed 2008;, Ginde 2009, Semba 2009), a power law fitted to the data yields the finding

hazard ratio = $4.46\text{x}(25(\text{OH})\text{D})^{-0.396}$ (p=0.95) (Grant, unpublished).

Estimate for a benefit of increasing serum 25(OH)D levels for Western Europe

Such serum 25(OH)D level-disease outcome relations can be used to estimate the reductions in mortality rates and economic burden of disease for countries or regions. The approach taken is to first determine the mean serum 25(OH)D level for the population, then use the level-outcome relations to estimate the reductions in disease outcome for the change in serum 25(OH)D level. While the percentage effect on mortality rate and economic burden from an increase in serum 25(OH)D level may not be the same as for incidence, this approach is a good starting point.

The estimate for the avoided premature death rate for Western Europe for increasing serum 25(OH)D levels from 50–63 nmol/L to 100 nmol/L is presented in Table 1.

Similar analyses have also been performed for other countries. A summary of such findings is given in Table 2.

Table 1. Estimate of avoided death rates for Western Europe for 2002 from increasing mean serum 25(OH)D levels from 50–63 nmol/L to 100 nmol/L (Grant et al. 2009).

Disease	Mortality rate*	Reduction **(%)	Avoided mortality rate*
Cancers	39.8	25	10.0 (6.0-14.0)
CVD	171.2	15	25.7 (8.6-42.8)
Dementia	17.0	10	1.7 (0.0-3.4)
Diabetes	12.4	15	1.9 (0.6-3.1)
MS	1.0	50	0.5 (0.4-0.6)
Lower airway infection	24.8	20	5.0 (2.5-7.4)
COPD, asthma	24.3	10	2.4 (0.0-4.9)
Other	97.7	0?	0?
Totals	388.2	12 (5-20)	47.2 (18.1-76.2)

* deaths/100 000/year;
** uncertainty estimated at $\pm$10 from given value; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; MS, multiple sclerosis

Table 2. Estimates of reduction in mortality rates from increasing serum 25(OH)D levels to 100 nmol/L for several countries.

Country	Rate	Avoided rate	Avoid (%)	Reference
Australia	417	61 (29-91)	15 (9-22)	
Canada	446	61 (30-93)	14 (7-21)	Grant et al. 2010
Netherlands	504	92 (55-128)	18 (11-25)	Grant & Schuitemaker, in press
USA	544	63 (34-113)	13 (6-21)	Grant 2009

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High-risk patients self-select for melanoma screening

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Abstract. Guidelines for the Management of Melanoma in Australia and New Zealand, published in 2008, describe population risk factors for melanoma. Screening those at high risk of melanoma may result in earlier diagnosis of melanoma in these subjects.

We evaluated risk factors in people attending a self-referred whole-body photography and sequential digital dermoscopy imaging service in New Zealand by examining data collected by MoleMap NZ over a 3-year period.

There were 27 090 patients, mostly of European ethnicity (97.1%). Compared to those diagnosed with melanoma, the mole mapping population tended to be younger and more likely to be female (60%). Risks for melanoma included history of melanoma (10%), actinic damage (27%), more than 50 common naevi (13%), fewer than 5 atypical naevi (16%), family history of melanoma in first-degree relative (15%), light-coloured hair (33%), blue eyes (45%) and a history of sunburn (90%). The risk factors were more pronounced in a subgroup of 94 patients diagnosed with melanoma.

Most screened patients had one or more significant risk factors for melanoma (95%). However, the impact of early diagnosis by mole mapping on the incidence and mortality of melanoma in New Zealand remains unknown.

Introduction

New Zealand has one of the highest incidence rates of invasive melanoma in the world. As survival from melanoma is strongly associated with depth of invasion, early detection of melanoma may reduce mortality and morbidity. This may be achieved by effective skin screening. Skin screening often refers to a visual examination of the whole body; however, it may also be undertaken using whole body photography and digital dermoscopy.

A private teledermatology service established in New Zealand in 1997 provides skin screening by mole mapping, i.e., whole body photography and digital images of macro and dermoscopy views of lesions of concern. The images are stored on a secure server. An experienced dermatologist reviews the images, and may make recommendations for management of specific lesions.

Accepted risk factors for melanoma include (Australian/NZ Melanoma Guidelines 2008):

- person's age and sex
- history of previous melanoma or non-melanoma skin cancer
- number of naevi (common and atypical)
- family history of melanoma
- skin and hair pigmentation
- response to sun exposure
- evidence of actinic skin damage (Figure 1)

Skin screening for melanoma is of greater benefit in people with more risk factors, as they are more likely to be correctly diagnosed with the disease than people with lower risk.

Material and methods

The database of a proprietary whole body photography and sequential digital dermoscopy screening systems for melanoma (MoleMap NZ, Unit L/383 Khyber Pass Road, Newmarket, Auckland, New Zealand) was queried for melanoma risk factor data of patients attending between 2005 and 2008.

In addition, a randomly selected subgroup of 94 patients with 100 histologically proven melanomas diagnosed by mole mapping was also analysed.

Figure 1. Moderate sun damage affecting the scalp.

Results

During the 3-year study period, 27 090 unique patients attended for mole mapping. It was the first visit for 6152 (22.7%). About 70% of patients were self-enrolled; others attended on referral by their general practitioner or other health professional.

There were 16 163 females (59.7%) and 10 927 males (40.3%). Overall, the average age was 41.2 years for females and 41.5 years for males. There were 808 patients over the age of 70 (2.1%) in the study population. Self-reported ethnicity was predominantly European (97.1%).

Table 1. History of melanoma or non-melanoma skin cancer.

	Whole population		Melanoma subgroup	
Melanoma				
Not significant	23,879	89.0%	44	47.8%
Unsure	438	1.6%		
>5 years ago	983	3.7%	12	13.1%
Recent or multiple	1,516	5.7%	36	39.1%
Total	26,816	100.0%	92	100.0%
Actinic damage				
Not significant	10,848	41.1%	21	22.8%
Some	8,375	31.7%	36	39.1%
Moderate	5,549	21.0%	23	25.0%
Severe	1,625	6.2%	12	13.1%
Total	26,397	100.0%	92	100.0%

A self-reported history of prior melanoma was given by 2499 individuals (9.4%), and was recent (less than 5 years) in 5.7%. Moderate to severe actinic damage, i.e., a history of non-melanoma skin cancer or actinic keratosis, was self reported in 27.2% (Table 1). Other data are summarised in Tables 2–4.

Table 2. Number of melanocytic naevi.

	Whole population		Melanoma subgroup	
Number of moles				
Not significant	16 089	64.6%	42	47.2%
Some (>5) moles >5mm	5 516	22.1%	20	22.5%
Many (>50) moles >2mm	3 309	13.3%	27	30.3%
Total	24 914	100.0%	89	100.0%
Atypical naevi				
Not significant	15 131	60.0%	25	29.8%
Few (0 - 5)	6 061	24.0%	34	40.5%
Some (5 - 15)	2 557	10.1%	15	17.8%
Many (>15)	1 482	5.9%	10	11.9%
Total	25 231	100.0%	84	100.0%

Table 3. Hair colour and skin pigmentation.

	Whole population		Melanoma subgroup	
Hair Colour				
Red	1 106	4.2%	5	5.6%
Blond	4 726	17.8%	11	12.2%
Light	3 043	11.4%	10	11.1%
Brown	15 496	58.2%	62	68.9%
Dark	1 099	4.1%	1	1.1%
Black	1 134	4.3%	1	1.1%
Total	26 604	100.0%	90	100.0%
Hair Colour				
Red	1 106	4.2%	5	5.6%
Blond	4 726	17.8%	11	12.2%
Light	3 043	11.4%	10	11.1%
Brown	15 496	58.2%	62	68.9%
Dark	1 099	4.1%	1	1.1%
Black	1 134	4.3%	1	1.1%
Total	26 604	100.0%	90	100.0%

Table 4. Response to sunburn.

	Whole population		Melanoma subgroup	
Fitzpatrick phototype				
Skin Type = 1	2 147	8.0%	7	7.7%
Skin Type = 2	14 560	54.1%	62	68.9%
Skin Type = 3	9 837	36.5%	22	24.4%
Skin Type = 4	356	1.3%	0	0
Skin Type = 5	29	0.1%	0	0
Total	26 929	100.0%	91	100.0%
History of sunburn				
Not significant	2 762	10.4%	3	3.2%
Some early	11 859	44.5%	37	39.4%
Many early	10 526	39.5%	4	4.3%
Some late	1 514	5.7%	50	53.2%
Total	26 661	100.0%	94	100.0%
Sun bed use				
Not significant	21 230	79.9%	79	85.9%
Occasional use	4 708	17.7%	10	10.9%
Frequent use	633	2.4%	3	3.3%
Total	26 571	100.0%	92	100%

The relative risks of the study population were compared with the relative risks described in the Melanoma Guidelines. Ninety-five percent of the screened population was assessed as having at least 1 risk factor; 71% had at least 2 risk factors and 32% had at least 3 risk factors.

The melanoma subgroup included 51 males and 43 females. There were 6 patients over the age of 70 in the melanoma subgroup (6.3%). Self-reported ethnicity was European in all cases (100%). A definite history of prior melanoma was given in 53.9% of 89 patients and was recent (less than 5 years) or multiple in 40.4%. Moderate to severe actinic damage was reported in 41.6% of 89 patients (Table 1): 30.3% of patients had more than 50 moles that were over 2 mm in diameter and 29.8% had more than 5 clinically atypical naevi (Table 2). A first-degree relative with melanoma was reported by 26.6%.

All of the melanoma subgroup was assessed as having at least 1 risk factor; 98.9% had at least 2 risk factors and 91.1% had at least 3 risk factors

Discussion

Several professional groups including the Cancer Society of New Zealand (2007) do not endorse routine skin screening for average risk individuals (US Preventive Services Task Force 2001). The Early Detection Advisory Group (EDAG 2006) stated that there is no high quality evidence from randomised controlled trials that screening for melanoma is effective in reducing mortality. In addition, it is not possible to conclude whether or not screening for skin cancer does more good than harm (possible harms including unnecessary biopsies and treatment). EDAG also commented *"There is broad agreement that individuals at high risk should be identified and offered surveillance."*

Conclusion

This study confirms that many of those attending for mole mapping are individuals at high risk of melanoma.

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Vitamin D status of a Dunedin sample, 2008–09: preliminary results

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Abstract. Serum 25(OH)D measurements varied seasonally among 170 Dunedin, New Zealand, participants with highest values in summer, followed by spring and then autumn. There was no evidence of any difference between men and women, or for those identifying themselves as outdoor workers. Vitamin D levels increased with increasing age, and decreased with increasing BMI. Participants identifying as Asian had the lowest mean 25(OH)D levels.

Introduction

A significant proportion of New Zealanders have sub-optimal levels of vitamin D, particularly Pacific, Maori, South Asian and older European people. Analyses of serum samples from adults in the 1997 National Nutrition Survey showed that 84% of adult New Zealanders had serum 25(OH)D_3 levels below 80 nmol/L (Rockell et al. 2006), the level which recent studies indicate is recommended for optimum health (Bischoff-Ferrari et al. 2006). Low levels of vitamin D have been implicated in a wide variety of health issues including cancer, diabetes and cardiovascular disease.

The results presented here are part of a larger study. The preliminary analyses were undertaken to explore relationships between serum 25(OH)D and other factors.

Methods

A community sample of 170 adults from Dunedin, New Zealand (latitude 45° S) was purposefully recruited to be equally spread across the sexes, main ethnic groups (New Zealand, European, Maori, Pacific and Asian), and the full adult range (18–80 years). The participants were followed up for 8 weeks during autumn, winter or spring (March to early December, in either 2008 or 2009). Data collected at the baseline interview included demographics (age, sex, ethnicity); occupation (including hours of outdoor work); usual sun exposure over the previous 4 weeks; food frequency data to record usual intake over the previous 4 weeks of foods known to be high in vitamin D; use of dietary supplements over the previous 4 weeks; weight and height to calculate Body Mass Index (BMI); and skin reflectance to measure skin pigmentation. Thereafter, weekly interviews were conducted to collect ultraviolet radiation (UVR) exposure data from personal dosimeters, clothing diaries, and food diaries. Blood tests were taken at the end of Week 4 and Week 8 and analysed for levels of 25(OH)D.

Using both week 4 and week 8 vitamin D levels, with robust standard errors used to account for the repeated measures, selected factors were examined in terms of their association with vitamin D, both univariately and multivariately. The 'effective season' was calculated using solstice and equinox dates based on the date four weeks before the blood test date. BMI (kg/height in metres^2) was transformed using fractional polynomials (1/BMI^2) because of its non-linear association, and so its effect is presented (see Table 2) for an increase from its 25th (24.3) to 75th (32.4) percentile. All other continuous variables were adequately modelled using linear associations.

Results

The sex and ethnicity distribution of the two-year Dunedin sample are presented in Table 1, along with measured serum 25(OH)D.

Table 1. Geometric mean 25(OH)D (nmol/L) in participants by sex, ethnicity, and year.

		Number (%)	Geometric mean 25(OH)D
Sex	Male	72 (42%)	39.53
	Female	98 (58%)	36.61
Ethnicity*	Maori	30 (18%)	38.96
	Pacific	40 (24%)	35.49
	Asian	46 (28%)	30.54
	NZ European	48 (29%)	50.95
Year	2008	84 (49%)	34.61
	2009	86 (51%)	41.24

*6 participants of 'other' ethnicity omitted from modelling

The unadjusted serum 25(OH)D levels are presented in Figure 1 with 95% confidence intervals by actual month of blood sample for all 170 Dunedin participants across both years. Levels were lowest in the winter months of July and August.

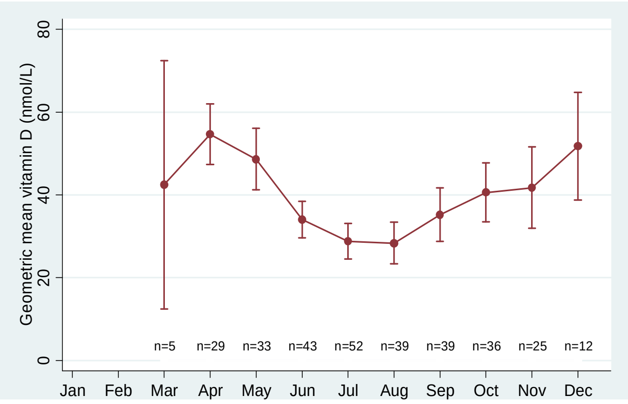

Figure 1. Unadjusted vitamin D blood level with 95% confidence intervals, by month of sample, using both week 4 and week 8 data.

The adjusted model is presented in Table 2. In the unadjusted model (data not shown) there was a tendency for 2009 vitamin D values to be slightly higher, but this effect was attenuated and no longer statistically significant in the adjusted model. Effective season was strongly statistically significant in both models, with highest values in summer, followed by spring, then autumn. There was no statistically significant difference between the sexes or for outdoor workers. Vitamin D levels increased with age and decreased with BMI in both models. In the unadjusted model, all ethnicities other than New Zealand European had lower vitamin D. However, after adjusting for other factors, only Asian vitamin D levels were statistically significantly lower than NZ European levels.

Table 2. Factors in the adjusted model for predictors of vitamin D blood level.

	Ratio of geometric means (95% CI)	p-value
Year (2009 c.f. 2008)	1.08 (0.94-1.24)	0.290
Effective Season (c.f. winter)		<0.001
Spring	1.38 (1.15-1.65)	
Summer	1.65 (1.36-2.02)	
Autumn	1.11 (0.96-1.29)	
Female (c.f. male)	0.95 (0.83-1.08)	0.416
BMI (25^{th} to 75^{th} percentile)	0.82 (0.71-0.93)	0.003
Age (per 10 years)	1.06 (1.02-1.11)	0.004
Ethnicity (c.f. NZE)		<0.001
Maori	0.96 (0.78-1.16)	
Pacific	0.89 (0.72-1.10)	
Asian	0.60 (0.50-0.73)	
Outdoor worker	1.11 (0.92-1.34)	0.281

Discussion

A surprising finding in this preliminary analysis is that vitamin D blood levels increased significantly with age. Previous studies (McKenna 1992, Rockell et al. 2006) have shown that older people tend to generally have lower vitamin D levels, although a recent Norwegian study found 25(OH)D levels to be higher in persons older than 50 years, compared with those younger (Moan et al. 2009). However, participants in our study may not represent a ‘typical’ older person, as they tended to be active, retired people who volunteered to participate in the project. Further analysis of the data collected on UVR exposure may show that increased time outdoors, compared with younger working participants, would help explain their higher vitamin D levels.

Lower levels of serum 25(OH)D have previously been associated with higher BMI (Konradsen 2008, Konradsen et al. 2008), and this was confirmed in the Dunedin sample.

Data previously collected in New Zealand found lower levels of serum 25(OH)D among Pacific and Maori (Rockell et al. 2006) compared with New Zealand Europeans, but did not specifically investigate Asian ethnicity. The current data clearly show that the lowest levels occurred among those of Asian ethnicity. Further analysis of the entire dataset will be undertaken to explore associations between 25(OH)D levels, UVR exposure and dietary factors.

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Sun protection and vitamin D

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Abstract Sun protection relies on behavioural sun avoidance, appropriate high UV protective clothing, sunglasses, broad-rim hats and sunscreen. Daily use of broad-spectrum sunscreen can significantly reduce UV-induced skin damage, BCC and SCC skin cancers and if used regularly in early life, can reduce lifetime skin cancers by 80% and might reduce naevus counts and subsequent melanoma risk. Sunscreen components are grouped into inorganic/physical and organic/chemical filters. Inorganic sunscreens are photostable, non-absorbed, non-sensitising and work by reflecting and diffusing UVR. Microionised forms improve cosmesis. Organic filters absorb UVR energy within specific wavelength ranges and are variably photostable or photoreactive. Sunscreen effectiveness varies among products due to composition, age, storage conditions, and consumer application. UVB filter effect is graded by SPF (sun protection factor) but there is no universally agreed grading for UVA, infra-red, visible light, or immunosuppression. UVA exposure may be more relevant for melanoma and photoageing. Physiological health benefits from UVA exposure are currently unidentified. Vitamin D is maximally produced in the skin at suberythemal doses within the UVB spectrum. The majority of epidemiological studies have found adequate vitamin D levels in those using regular sunscreen. Hopefully future sunscreens will provide better protection beyond UVB.

UV effects

Nonmelanoma skin cancer incidence is directly related to latitude, and long-term chronic ultraviolet (UV) exposure whereas melanoma risk is better related to annual, ambient and acute intermittent high UV exposure, (Armstrong & Kricker 2001, De Gruifi 2002). UVB impacts directly on cell DNA and proteins whereas UVA is a strong immune suppressant, penetrates deeper into the skin and contributes to photocarcinogenesis and photoageing by producing damaging oxygen free radicals (Pathak 1997, Urbach 2001). Effects of excessive UV exposure persist lifelong. Vitamin D, important for general health (Holick et al. 1980), is optimally produced in the skin from UVB, at a very low dose, 0.25 of the minimal erythema dose. Maximal UVB levels are typically found around noon. The ratio of UVA to UVB is 20:1 (Kullavanijaya 2005) so longer sun exposure in any day increases cumulative UVA-induced damage. Daily use of broad-spectrum sunscreen can significantly reduce UV-induced skin damage, basal and squamous cell carcinomas (BCC, SCC), dysplastic naevi and if used regularly in early life, might reduce naevus counts and subsequent melanoma risk (Fourtainer et al. 2003, Marks 2000, Naylor et al. 1995, MacLennan et al. 2003, Huncharek & Kupelnick 2002, Rigel 2002).

Sun protection

The NZ Cancer Society recommends sun avoidance behaviour during peak UV index (UVI >8) hours, and combined measures of sun protection using appropriate clothing, wide-brimmed hat, sunglasses and broad spectrum sunscreen when outdoors in UVI >3.

UV protection factor (UPF), assessed by measuring transmission of UVA and UVB through fabrics with a spectrophotometer, grades UV protection from clothing. Higher UPF is achieved by tighter weave, darker colours, and distance of fabric from the skin. Hydration alters UPF differently in different fabrics, e.g., a typical summer cotton T-shirt provides UPF=7 but when wet the UPF =3, whereas fabrics made of viscose or silk may increase UPF when wet. Clothing UPF should be over 30 and the design should cover the upper body (base of neck down to hip and across shoulders down to ¾ of upper arm), and lower body from waist to knee (Kullavanijaya 2005).

Depending on the fabric, design, brim width and the way they are worn, hats provide variable sun protection for the head, face and neck. A wide brimmed hat (over 7.5 cm) has SPF 7 for nose, 3 for cheek, 5 for neck and 2 for chin. Medium-brimmed hats (2.5–7.5 cm) provide SPF 3 for nose, 2 for cheek and neck, and none for chin. Narrow-brimmed hates provide SPF 1.5 for nose and little protection for chin and neck (Carolyn et al. 1997).

Sunglasses which absorb 99–100% of the full UV spectrum (up to 400 nm) should be worn to protect against cataracts and eye cancer (Davis 1990).

Non-clothed skin may achieve partial sun protection from the use of sunscreen. Sunscreen components are grouped into inorganic (physical /non-chemical) and organic (‘chemical”) filters. Titanium dioxide and zinc oxide are inorganic, photostable, not absorbed systemically, and have not been reported to sensitise (cause allergic skin reactions). They work by reflecting and diffusing UVR (Forestier 2008). Decreasing particle size from 200 to 500 nm to microionised form (10–50 nm) reduces the cosmetically unacceptable white colour but shifts protection towards shorter wavelengths unless the titanium dioxide and zinc oxide particles are coated with dimethicone or silica. Organic filters absorb UVR energy variably within a specific range of wavelengths depending on their chemical structure and the absorbed energy is converted to unnoticeable infrared energy (Kullavanijaya 2005). The chromophores are “photostable” if able to absorb UVR photons repetitively, “photounstable” if the filter rapidly loses its absorption capacity and protective potency, and “photoreactive” if absorbed UV photons create photoexcited molecules which then interact with skin biomolecules, ambient O_2 or other sunscreen ingredient. Effective UVB filters include para-aminobenzoic acid (PABA) derivatives (e.g., octyl dimethyl para-aminobenzoic acid), cinnamates, salicylates, octocrylene and phenylbenzimidazole sulfonic acid. Octyl methoxycinnamate degrades into a photoproduct when exposed to sunlight but this is mitigated if encapsulated into nanoparticles. In addition to titanium dioxide and zinc oxide, effective UVA filters include benzophenones, avobenzone, and menthyl anthranilate. Benzophenones and avobenzone are photolabile so are frequently combined with other ingredients, e.g., salicylates, micronised zinc oxide or titanium dioxide to enhance their photostability. “Broad-spectrum” filters have a high level of absorption in both the UVB and UVA ranges. Because sunscreen stability (particularly UVA cover) is variable, sunscreens should be frequently re-applied, stored away from heat and sunlight and discarded at expiry date.

The standard method for Sun Protection Factor (SPF) rating, the ratio of the time to produce minimal UVB-induced skin erythema from the sunscreen compared to unprotected skin, involves applying 2 mg/cm^2 of the product, much more than the 0.5 mg/cm^2 typically applied by consumers (Bech-Thomasen et al. 1993). The *effectiveness* of sunscreen SPF may be exponentially related to the amount applied so the true SPF may be as little as a 4th root of the claimed SPF! Arguably the SPF rating ought to be assigned as consumers use the product i.e., at 0.5 mg/cm^2 rather than 2 mg/cm^2. There is no universally agreed grading for UVA, infra-red, visible light, or immunosuppression. Perspiration, swimming and clothing reduce skin sunscreen. Both the Cancer Society and the Health Sponsorship Council of NZ recommend that an average-sized adult needs to use one teaspoon of sunscreen on each limb, on both torso sides, and half a teaspoon to the face, neck and ears to achieve adequate coverage, and to reapply frequently.

Vitamin D not reduced by sunscreen use

Theoretically a high SPF-rated sunscreen provides better UVB protection and thus would impair vitamin D production. However, normal regular sunscreen usage has not been associated with vitamin D insufficiency in most studies (Farrerons et al. 2001, Marks et al. 1995, Norval et al. 2009) except (Matsouka et al. 1987), possibly because insufficient sunscreen is applied and sunscreen users may expose themselves to more sun (Im et al. 2010).

Photo-antioxidants may help reduce UVA-induced damage. Topical antioxidants tend to be unstable but may enhance sunscreen efficacy, e.g., vitamins C and E. Dietary photoprotection flavonoids and polyphenolic compounds found in many fruits and vegetables, some plant extracts, and omega-3 polyunsaturated fatty acid are probably better (Kullavanijaya 2005).

Current best photoprotective recommendations involve judicious sun avoidance, photoprotective clothing, wide-brimmed hat, sunglasses and use of broad spectrum sunscreens. Additional protection may be gained from dietary photoantioxidants. Future sunscreens may incorporate better UVA and immune protection, without impeding vitamin D production.

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UV Index variations (1960–2006) and melanoma skin cancer incidence in Australia

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Abstract. Surface ultraviolet (UV) radiation can have important impacts on human health and terrestrial ecosystems. In humans, increased exposure to UV radiation increases the risk of skin cancer. In Australia, public communication campaigns for skin cancer prevention include the promotion of daily UV forecasts. However, it is estimated that nearly 450,000 Australians still get skin cancer every year, including more than 10,000 cases of melanoma, the most dangerous form of skin cancer. Hence, it is important to monitor Australia's UV radiation levels over time, in particular, because of the effects cumulative exposure can have on humans. The amount of surface UV radiation strongly depends on stratospheric total ozone amounts, geographical location, date, and time of day. Ozone absorbs part of the UV radiation over the wavelengths 300–400 nm, which is the UV radiation that is most important for humans and ecosystems. Reductions of stratospheric ozone result in surface UV radiation increases. Variations in surface radiation related to ozone depletion have been reported for several locations world wide during the last few years. In this paper we present and discuss the variations in the UV Index and melanoma skin cancer incidence for Australia from 1968 to 2008.

UV Index variations (1960–2006)

We used gridded monthly average total ozone measured by NASA's Total Ozone Monitoring Spectrometer (TOMS), Ozone Monitoring Instrument (OMI), ECMWF's ERA40 reanalysis monthly total ozone, and meteorological fields from the Bureau of Meteorology climate model, as input to the UV radiation code, to calculate local-noon clear-sky UV Index (Lemus-Deschamps et al. 2004, 2006). UV Index levels below 3 are considered low, 3 to 5 moderate, 6 to 7 high, 8 to 10 very high, and above 11 extreme. The associated colour code used and suggested sun protection is illustrated in Figure 1.

Figure 1. UV Index levels categories and sun protection tips.

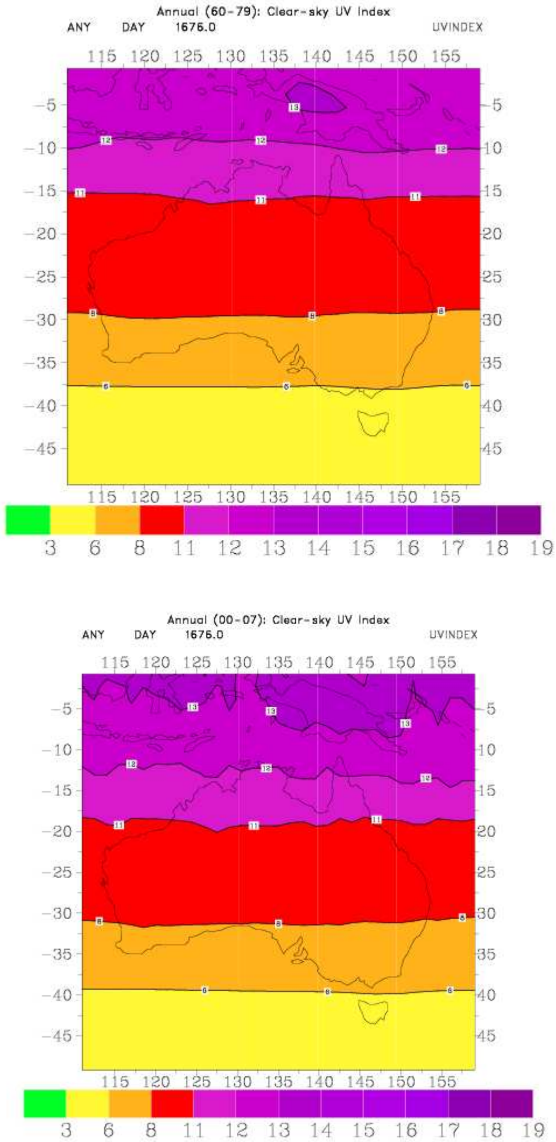

Figure 2. Annual clear-sky UV Index average over 1960–79 and 2000–07.

The annual average over (1960–79) and (2000–07) (Figure 2) shows that, for the 20th century, the UV Index level "11" is displaced about 5° from 15° to 20° S. UV level 8 (28° S, top panel Figure 2) and level 6 (37.5° S, top panel Figure 2) also are displaced about 5° south (bottom panel Figure 2). The day-and-time of the year, latitude, longitude, altitude, uv-surface-albedo, ozone absorption dependence on temperature, Rayleigh scattering, solar irradiance, aerosols are taken into account to calculate clear-sky local-noon UV Index. Averages for each month over the period (1960–70) were calculated and subtracted from the monthly UV Index. The long-term spatial and temporal deviations from 1960 to 1970 were calculated for North (10–29° S), Central (29–37° S), and Southern (37–45° S) Australia (Figure 2).

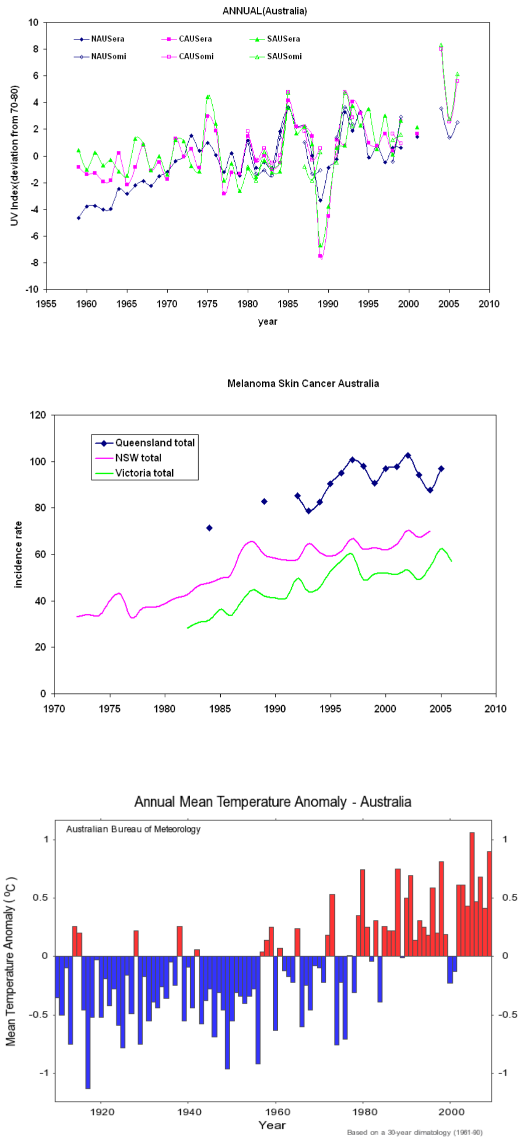

Figure 2. Annual monthly clear-sky UV Index (%) deviation from 1960 to 1970, calculated for North (10–29°S), Central (29–37°S) and South (37–46°S) of Australia, non-melanoma skin cancer incidence for Queensland (137–157°E,12–25°S) New South Wales (140–167°E,12–35°S) and Victoria (140–167°E,32-40°S), and Australia's annual mean temperature anomaly (NCC, Bureau of Meteorology).

An ongoing increase of clear-sky UV Index level is observed for all regions since the 1970s. It is well known that Australians love the outdoor life style. Hence, it is more likely that they will be out of doors and be subject to UV sun exposure when temperatures are warm and there are clear skies. Figure 2 shows that temperature has been on the rise since 1990. This, combined with people's outdoor living style and the UV increases, could result in increased exposure to high UV levels, potentially resulting in melanoma skin cancer incidence increases. For North and Central Australia, during winter UV Index levels are still high (not shown here); however, people could have the perception that UV levels are low because it is winter. This, combined with warmer, but more pleasant, temperatures than in summer, when it is more likely that people will carry out outdoor activities, could result in increased exposure to high UV radiation levels. For southern Australia, UV increases are observed mostly during summer (not shown here), when high temperatures are likely, and people are more likely to be outdoors.

Summary

For Australia, the results suggest that there is a connection between increases in UV levels, exposure to UV radiation during hot weather, and melanoma incidence. An ongoing increase in melanoma skin cancer (Figure 3) is observed, being more pronounced to the north. The results show that UV Index levels have been on the rise since the 1970s. Having said that, we can not exclude that people who love outdoor activities are most likely exposed to high levels of UV radiation when hot weather and clear skies prevail. Winter UV levels in northern and central Australia are of particular interest, since the UV levels are high all year around. Hence, the perception that UV levels are low during winter, may be misleading.

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Action spectrum for vitamin D synthesis

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Introduction

Exposing the skin to UV radiation initiates vitamin D synthesis: 7-dehydrocholesterol (located in the membranes of skin cells) absorbs UVB photons and converts into previtamin D, which then thermally isomerises into vitamin D over a period of 12 to 24 hours.

UV levels decrease with increasing latitude and the wavelength composition also varies by latitude, across the day, and across the year. Given the importance of vitamin D for our health, it is essential to understand how vitamin D-effective UV varies by region and by season.

To measure the level of vitamin D-effective UV, an action spectrum is used. An action spectrum for producing previtamin D (the initial photochemical reaction) is already in existence. This was obtained by MacLaughlin et al. (1982). The CIE recently adopted this as the standard action spectrum for previtamin D synthesis in human skin (CIE 2006). The CIE action spectrum presents the effectiveness (in relative units) of the UV wavelengths at synthesising vitamin D (Figure 1). Vitamin D-effective UV irradiance (W/m^2) is determined by weighting the ambient UV spectrum with this action spectrum, and then integrating across the wavelength range.

The CIE action spectrum has some limitations. In particular, in the original 1982 experiments the monochromatic UV source used to obtain the action spectrum had a relatively large bandwidth, ranging from 6 to 10 nm. This may have decreased the precision of the measurements that were conducted (at 1 nm intervals) to assess the previtamin D-producing potential of each wavelength.

Here we use an *in vitro* model to test the effectiveness of various UVB wavelengths at producing vitamin D, and then compare the findings with the CIE previtamin D action spectrum.

Method

We used an *in vitro* model consisting of 7-DHC dissolved in high-grade ethanol (Olds et al. 2008). Individual samples were made by placing a small volume of this solution into a UV-transmissive quartz cuvette.

Samples were then exposed to monochromatic radiation from 290 to 320 nm, in 5 nm intervals. Three samples were exposed at each wavelength (total of 21 samples).

UV exposures were conducted with an irradiation monochromator (IM), which was calibrated to the NIST standard of irradiance. The bandwidth of the IM (1.7 nm) is considerably narrower than that used in the original 1982 study. A constant dose of 20 J/m^2 of unweighted UV was given at each wavelength.

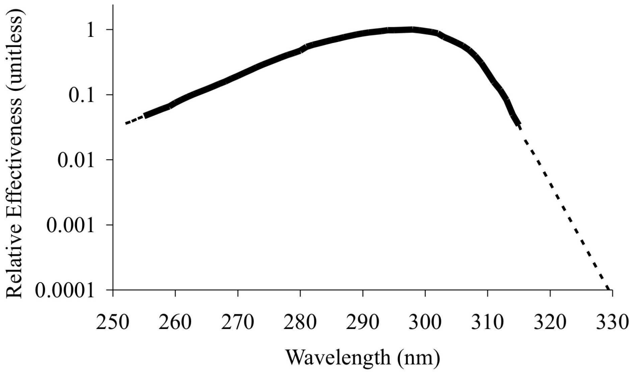

Figure 1. The CIE action spectrum for previtamin D synthesis. The solid region is the data that was obtained by MacLaughlin et al. in 1982. The dashed region is data extrapolated by the CIE (CIE 2006).

In the *in vitro* model, vitamin D is measured as the endpoint (whereas previtamin D was the endpoint in the MacLaughlin et al. experiments). Hence, after exposing each sample, it was placed into a vial and incubated at 37ºC (physiologic temperature) for 24 hours. This allowed sufficient time for the majority of previtamin D in the sample to convert into vitamin D. Since the incubation time and temperature were standardised for every sample, these two endpoints (previtamin D and vitamin D) should be similar and allow us to compare our results with the CIE action spectrum.

After precisely 24 hours, the amount of vitamin D formed in every sample was analysed by high-performance liquid chromatography (HPLC), which is considered a very accurate measurement technique.

Finally, the mean vitamin D production was calculated for the three samples at each wavelength. These data were normalised to unity (1) at the peak (at 295 nm) and plotted as a function of wavelength.

Results

Figure 2 shows the data we obtained, based on exposure of the *in vitro* samples to monochromatic UV radiation (1.7 nm bandwidth). This figure also shows the currently accepted CIE action spectrum for comparison. It is apparent that the vitamin D production in the QUT data decays earlier (at a shorter wavelength) than in the CIE action spectrum. This cut-off is very important from a biological point of view, because it defines the range of wavelengths that will initiate vitamin D synthesis. Very little UVB radiation below 290 nm reaches ground-level on Earth. Therefore, a small shift in the cut-off would have a large impact on the measured level of vitamin D-effective UV.

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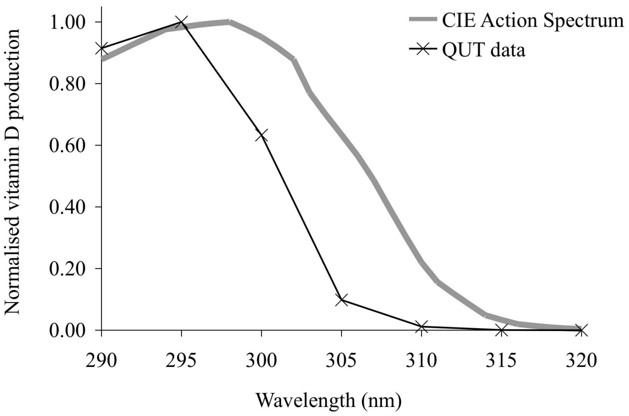

Figure 2. Normalised vitamin D production (QUT data), to allow comparison with the currently accepted CIE previtamin D action spectrum.

Discussion

In this work, we used a narrow-bandwidth UV source to test the vitamin D-effectiveness of UVB wavelengths, for comparison with the currently accepted CIE action spectrum. The data we obtained, when plotted, showed vitamin D was produced by a narrower range of wavelengths than the CIE action spectrum suggests. Since the CIE action spectrum was obtained with a wider bandwidth UV source, it seems that this may be the reason for its broader shape.

A limitation of the *in vitro* model is that it ignores the optical properties of skin. Skin is comprised of various layers that absorb and scatter UV. It also contains DNA, RNA, proteins and melanin that absorb UV before it can reach 7-DHC. The original MacLaughlin et al. action spectrum was obtained for skin; nonetheless our finding that the effective wavelength-range may be narrower should still be valid: there should be *more* vitamin D produced in ethanol, for a given dose of UV, than in skin because ethanol is more transparent to incoming UV. However, this was not the case – the CIE action spectrum is higher than the QUT data over the region from about 295 to 315 nm (Figure 2). Therefore, it seems that the narrower width of the QUT data, compared to the CIE action spectrum, can be attributed to the use of a narrower bandwidth UV source in this work.

To highlight the effect of these results when measuring vitamin D-effective UV levels, a solar UV spectrum for Queenstown (NZ) was obtained using the TUV model[3] (Figure 3) (midday, wintertime, 300 DU ozone concentration, clear-sky day). We weighted it with the CIE action spectrum as well as the QUT data (to weight the solar spectrum, the QUT data were interpolated to 1 nm intervals using a simple linear interpolation between adjacent 5 nm datapoints, to create a simple action spectrum). As shown in Figure 3, the level of vitamin D-effective UV is approximately 5-fold higher when measured with the CIE action spectrum, compared with using the QUT data. This is a considerable difference, resulting from the narrower width of the QUT data compared with the CIE action spectrum.

[3] http://cprm.acd.ucar.edu/Models/TUV/Interactive_TUV/

Conclusion

We believe that the data presented here suggest that the CIE action spectrum may need to be reviewed. The QUT data imply that a narrower range of wavelengths is responsible for synthesising vitamin D than the current CIE action spectrum (Figure 2) would suggest. Therefore, using the CIE action spectrum would result in larger measurements of the vitamin D-effective irradiance. This may lead to overestimates in the available level of vitamin D-effective solar UV, in any given location. These matters will be explored elsewhere in more detail (Olds et al. unpublished results).

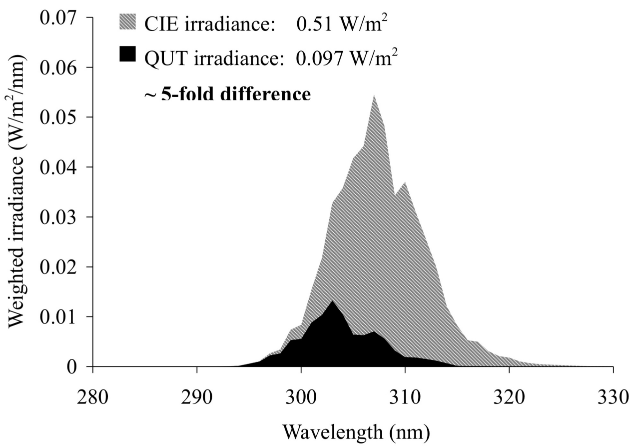

Figure 3. The solar spectrum for Queenstown after being weighted. Using the QUT data as a simple action spectrum, there would be approximately 5-fold less vitamin D effective UV than the CIE action spectrum would predict, in this location.

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Effects of clouds and aerosols on UV radiation measured at Lauder, New Zealand

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Abstract. Nine years (2000–08) of 1-minute resolution measurements at Lauder, New Zealand, have been analysed. Data available include global solar radiation (hereafter, GR), direct solar radiation (BR), diffuse solar radiation (DR), low wavelength downward radiation (LW), erythemally-weighted UV radiation (UV), total ozone column (TOZ), aerosol optical depth (AOD) at 412, 500, 610, 778 and 867 nm, and cloud cover information from a TSI camera: sky fraction with opaque (OP), thin (TH) and total (CFTSI) clouds. Another estimation of the cloud fraction is available from a short wavelength based algorithm (CFSWA). A first overview of the data is shown and effects of clouds and aerosols on UV radiation are investigated.

Data overview

Monthly mean values of daily GR irradiation and UV dose are plotted in blue in Figures 1 and 2, respectively. In red, only the days with mean CF<10% are included. The shaded area around the data points represents the standard deviation of the mean. The comparison between GR and UV highlights the larger summer:winter ratio for the latter than for the former. While for daily GR irradiation this ratio is around 5, for the UV it is 15.4.

Clouds have different effects on each type of radiation. The mean reduction by clouds for GR is 27.5% (ranging from 22.3% to 31.5%), and for UV the reduction is 22.5% (14.2–28.5%). This result is expected since the UV reaching the ground surface has a larger portion of scattered radiation compared to GR.

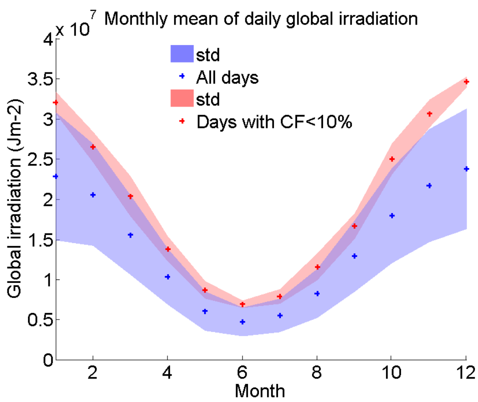

Figure 1. Monthly mean of daily global irradiation. In blue, all days are considered; in red, just days with mean CF<10% are included. Shaded bands account for the standard deviation of the mean (+/- σ).

The monthly average of the maximum daily UVI value recorded is shown in Figure 3. A large summer:winter winter contrast of 12 to 1 is also found.

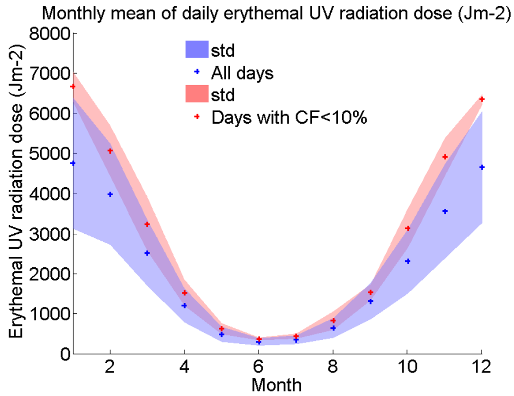

Figure 2. The same as for Figure 1 but for UV.

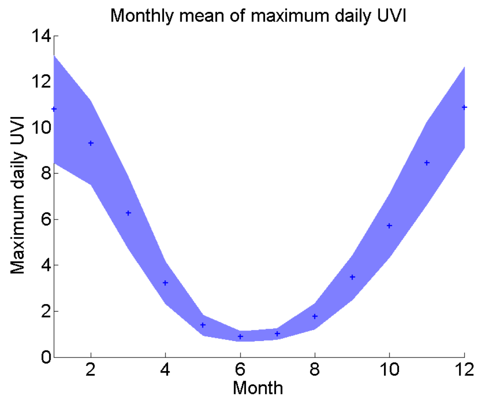

Figure 3. Monthly mean of maximum daily measured UVI.

Monthly mean values of the mean daily cloudiness (in % of sky covered by clouds) are plotted in Figure 4 for both CFTSI and CFSWA (Long et al. 2006). The overall cloudiness is about 60% in Lauder according to both methods and has a weak annual variation.

The CFSWA method shows larger CF values, especially for the winter months when the methods can differ up to about 10%, on average.

Besides the solar zenith angle (SZA) and clouds, which, in this order, are the main factors affecting UV at a certain location, TOZ is the third factor. Figure 5 shows monthly means of the daily mean TOZ at Lauder, showing a clear spring:autumn seasonality. This variation in ozone leads to less UV in spring (down to 261 DU) than in autumn (up to 356 DU) which can be seen in Figures 2 and 3.

Aerosols in the atmosphere extinguish the overall UV reaching the surface and the most important parameter to explain this effect is AOD which depends on the wavelength. Monthly means of the daily mean measured AOD at 412, 500, 600, 778 and 867 nm are shown in Figure 6. Larger AOD values are observed for lower wavelengths except at 500 and 610 nm, which are quite similar.

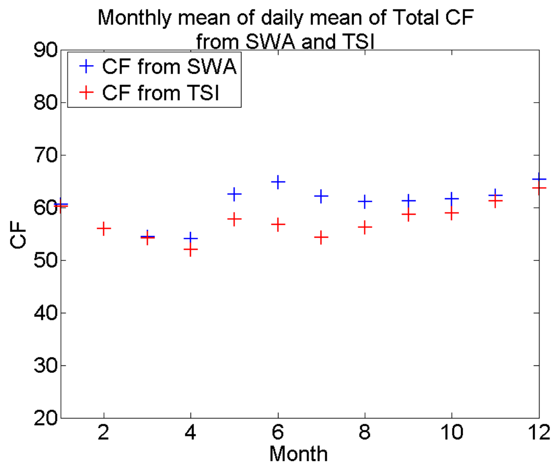

Figure 4. Monthly mean of mean daily cloud fraction according to the two considered methods.

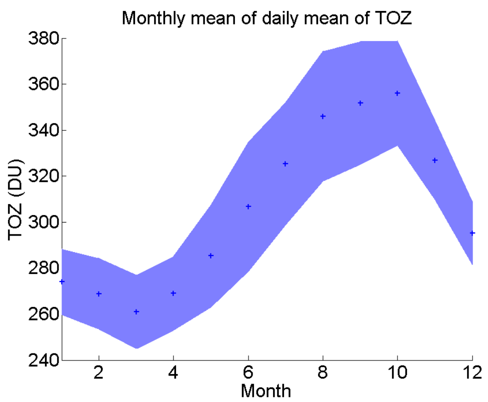

Figure 5. Monthly mean of the daily mean TOZ. The shaded band accounts for the standard deviation of the mean (+/- 1σ).

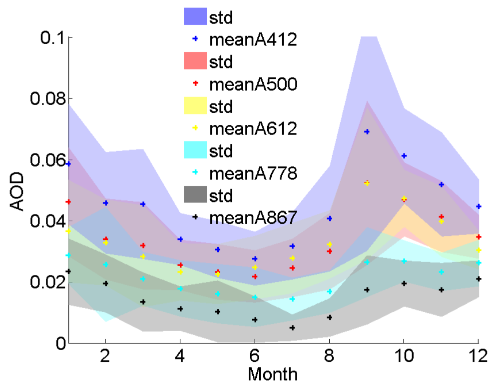

Figure 6. Monthly mean values of the daily mean AOD at several wavelengths. The shaded band accounts for the standard deviation of the mean (+/- 1σ).

Searching for cloud enhancements

The effect of clouds on UV can be investigated through cloud modification factors (CMF) defined as the ratio between the measured UV (affected by clouds) and an estimation of UV for cloudless sky conditions. To get these clear-sky calculations a simple parameterisation (referred to as PTUV) by Badosa et al. (2005) was used.

Figure 7 shows the CMF vs CFTSI plots for several SZA values for minute data with sun visible (not obscured by clouds). It is seen that, as CFTSI rises, so does the CMF values and this is more important for low SZA; as SZA increases the effect gets less important. These enhancements are caused by multiple reflections caused by clouds, which increase the diffuse UV radiation reaching the surface.

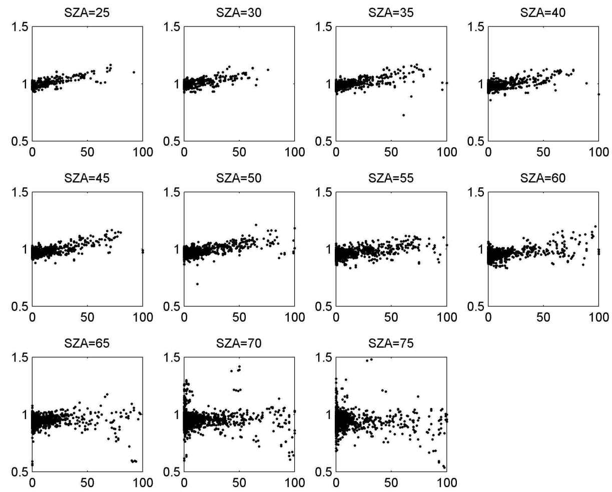

Figure 7. CMF vs CF for several SZA values. Only data points with un-obscured sun are included.

Acknowledgments

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Determinants of vitamin D in a multi-ethnic sample of Auckland residents

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Abstract. People in New Zealand have low levels of vitamin D compared to those in other countries. Suboptimal levels of serum 25-hydroxyvitamin D (25(OH)D) are associated with a range of different diseases, including cancer, heart disease, diabetes and high blood pressure. This cross-sectional study aims to determine factors that influence vitamin D status in a multi-ethnic sample of Auckland residents. Mean 25(OH)D varied with season, with the level higher in autumn compared to winter ($p<0.0001$). Mean 25(OH)D also varied with age, where levels were lower in ages 34–49 y than in 65–85 y ($p=0.018$). Females had higher mean 25(OH)D than males ($p=0.009$), and among the ethnic groups, Europeans had the highest and Asian & Other the lowest ($p<0.0001$). Those who liked to get a suntan had higher mean 25(OH)D levels than those who didn't ($p=0.026$). Mean levels of 25(OH)D did not vary with frequency of sunscreen usage.

Background

New Zealanders have low vitamin D levels (measured as serum 25-hydroxyvitamin D [25(OH)D]) (Livesey et al. 2008, Rockell et al. 2006). The levels vary with ethnicity, with the lowest found in Pacific and the highest in Europeans (Rockell et al. 2006). Studies also indicate a seasonal variation in 25(OH)D, with highest levels during summer and autumn, and lowest during winter Rockell et al. 2006, Livesey et al. 2008). This may be due to the differences in UVB irradiance, which is the strongest determinant of vitamin D status (Webb et al. 2006). Irradiation of skin with UVB initiates the photochemical conversion of 7-dehydrocholesterol to vitamin D_3 (Webb et al. 2006). The skin melanin content absorbs UVB radiation, and reduces the amount of vitamin D3 produced per time unit (Holick 2004, Webb et al. 2006) Personal UV irradiation varies with individual (ethnicity, age, clothing, and personal behaviour) and ecological factors (latitude, season, time of day, ozone amount, cloud amount, aerosol and reflectivity of the surface) (Webb et al. 2006).

Levels of 25(OH)D between ~about 80–125 nmol/L are considered to be in the optimal range, and concentrations lower than this may be associated with increased risk of cancers, heart disease, high blood pressure, diabetes, infections, fractures, myopathy, autoimmune diseases, osteomalacia and rickets (children) (Holick 2004).

The aim of this study was to identify determinants of 25(OH)D concentrations in a multi-ethnic sample of Auckland residents.

Methods

This is a cross-sectional study, funded by Health Research Council of New Zealand, with 317 adult volunteers (age 18–85 years) recruited from community groups in Auckland. The sample had twice as many females as males and a wide ethnic distribution. Throughout 2008–09 the volunteers completed a baseline questionnaire on demographic variables, sun-behaviour (including sunscreen usage) and attitudes towards sun tanning. Four weeks later, a blood sample was taken to measure 25(OH)D using liquid chromatography-tandem mass spectrometry in Christchurch. The date when the individual's blood samples were taken was used to divide the study sample into three seasonal groups. March–May was defined as autumn, June–August as winter and September–November as spring (no blood tests were taken during December–February). The baseline questionnaires were analysed along with the 25(OH)D measurements, using the chi-square test & analysis of variance (SAS, v. 9.1).

Results

The unadjusted mean 25(OH)D in the study sample ($n=317$) was 56.9 (SD 28.6) nmol/L. Concentrations of 25(OH)D varied with demographics and season (Table 1). Mean 25(OH)D was higher in females than males, and also varied with age, being higher in ages 65–85 y than in 35–49 y. The mean 25(OH)D was highest in Europeans, followed by Maori, then Pacific, and lowest in Asian & Other. It also varied with season, being higher in autumn (March–May) than winter and spring.

The proportion of those who liked to get a suntan varied with age, being largest in ages 18–34 y (47%), followed by 35–49 y (31%), 50–64 y (26%), and lowest in ages 65–85 y (24%) ($p=0.005$). A trend was seen in the proportion of those who liked to get a suntan by ethnicity. Although not significant ($p=0.1$), the highest proportion was found in Europeans (41%), followed by Maori (34%), then Pacific (30%), and then Asian & Other (22%). Mean 25(OH)D was higher in the group who liked to get a suntan than in those who did not (Figure 1).

Sunscreen use was more common in females than males ($p=0.0005$), and was highest in ages 18–34 y and declined with increasing age ($p<0.0001$). Frequency of sunscreen use varied with ethnicity, being highest in Europeans, followed by Asian & Other, and then Maori, and lowest in Pacific ($p<0.0001$). There was no association between sunscreen use and 25(OH)D (Figure 2).

Table 1. Mean 25(OH)D by age, ethnicity, gender & season adjusted for each other. *Reference category for mean difference and p-value.

Variables	25(OH)D mean (SE) nmol/L	Mean Difference (SE)	P-value
Sex			
Female (n=206)	59.4 (1.7)	7.9 (3.0)	0.01
Male* (n=111)	51.5 (2.4)	-	-
Age group (years)			
18-34 (n=83)	56.7 (2.7)	7.5 (4.1)	0.07
35-49 * (n=72)	49.2 (3.1)	-	-
50-64 (n=86)	56.4 (2.7)	7.2 (4.0)	0.07
65-85 (n=76)	59.2 (2.9)	10.0 (4.2)	0.02
Ethnic group			
European (n=68)	65.7 (3.1)	23.6 (4.1)	<0.0001
Maori (n=87)	60.9 (2.7)	18.8 (3.9)	<0.0001
Pacific (n=86)	52.8 (2.8)	10.7 (3.9)	0.007
Asian & Other (n=76)	42.1 (2.9)	-	-
Season			
Mar-May (n=104)	71.9 (2.5)	27.7 (3.5)	<0.0001
Jun-Aug* (n=92)	44.2 (2.7)	-	-
Sep-No) (n=118)	50.1 (2.4)	5.9 (3.6)	0.10

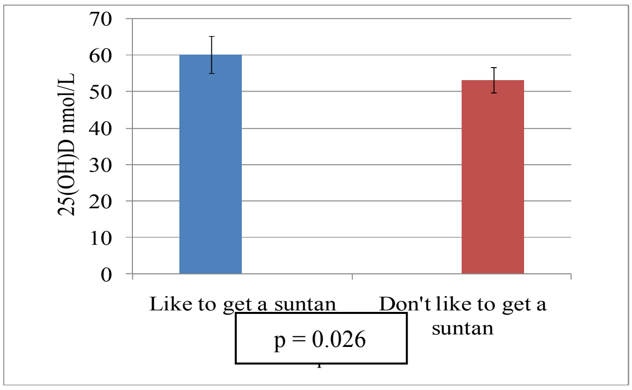

Figure 1. Mean 25(OH)D by whether or not 'like to get a suntan' adjusted for season, gender, ethnicity and age.

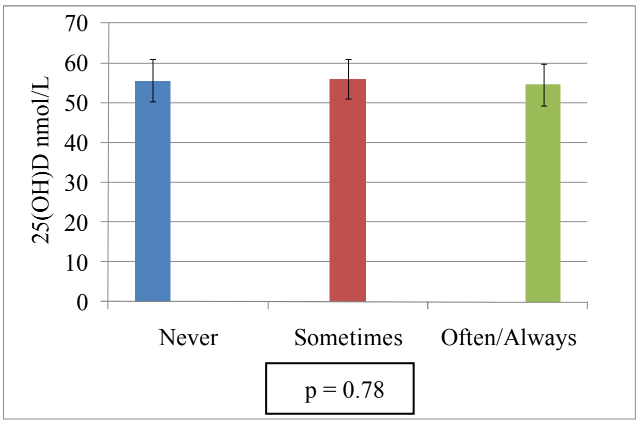

Figure 2. Mean 25(OH)D by frequency of sunscreen use adjusted for season, gender, ethnicity and age.

Discussion

The study sample mean 25(OH)D level is lower than optimal, in accordance with previous studies carried out in New Zealand (Rockell et al. 2006, Livesey et al. 2008). This may predispose Auckland residents to a number of diseases. The seasonal and ethnical variations in 25(OH)D seen in this study are consistent with previous publications (Rockell et al. 2006, Webb et al. 2006, Livesey et al. 2008). Few studies carried out in New Zealand, to our knowledge, have had people of Asian origin as a main part of an ethnic group. This makes the study results, referring to Asian & Other, of special interest. People of the ages 35–49 y had significantly lower mean 25(OH)D levels than ages 65–85 y. This may be explained by a higher fraction of time spent outdoors by the latter.

Females had higher mean 25(OH)D than males; this finding is inconsistent with previous results (Rockell et al. 2006, Scragg et al. 2007). Females used sunscreen to a greater extent than males, but frequency of sunscreen use was not associated with 25(OH)D levels. Frequency of sunscreen use declined with increasing age. It also varied with ethnicity, being highest in Europeans and lowest in Pacific. The lack of correlation between sunscreen use and 25(OH)D levels could be explained by increased sun exposure in those who use sunscreens.

This study indicates an association between 25(OH)D levels and a positive attitude towards sun tanning. The proportion of those who liked to get a suntan declined with age. A trend was seen among the different ethnicities, with the proportion of those who liked to get a suntan being highest in Europeans and lowest in Asian & Other.

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On behalf of the rest of the research team – Richard McKenzie, Tony Reeder, Alistair Stewart, Ben Liley, Paul Johnston, Debbie Raroa, Carol Taylor & Jan Jopson.

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Thinner melanomas detected by digital monitoring

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Abstract. Although survival from melanoma is strongly associated with depth of invasion, there is no agreement as to the role of screening for melanoma. We compared the characteristics of 100 melanomas diagnosed through a self-referred whole-body photography and sequential digital dermoscopy imaging service to those diagnosed through conventional methods as represented by data held by the New Zealand Cancer Registry (NZCR). There were 52 invasive and 48 in-situ melanomas; 90% were superficial spreading type, 6% were lentigo-maligna type and 4% were nodular on histology. Forty-eight were diagnosed on the first visit and the rest by serial digital dermoscopy. Thirty-five percent of patients reported having had a previous primary melanoma. In 60%, the patients had been concerned by the lesion, the rest (40%) were detected solely by screening.

Compared to the NZCR, patients diagnosed by whole-body photography and sequential digital dermoscopy screening had thinner melanomas: 69% were less than 0.75 mm Breslow thickness compared to 52% of NZCR melanomas; only 1.9% were thicker than 3 mm compared to 10.8% of NZCR melanomas.

Screening with whole-body photography with sequential digital dermoscopy detects melanoma at an earlier stage than conventional diagnostic methods.

Introduction

Even though survival from melanoma is strongly associated with depth of invasion, there is no agreement as to the role of screening for melanoma. Neither the Cancer Society of New Zealand (2006), nor the Cancer Council Australia (2007), currently recommend routine skin screening for average risk individuals. This is similar to the advice of the US Preventive Services Taskforce (2001). Despite this, there is increasing evidence that melanomas detected during a screening examination are thinner than melanomas not so detected (Geller et al. 2003, Koh et al. 2006).

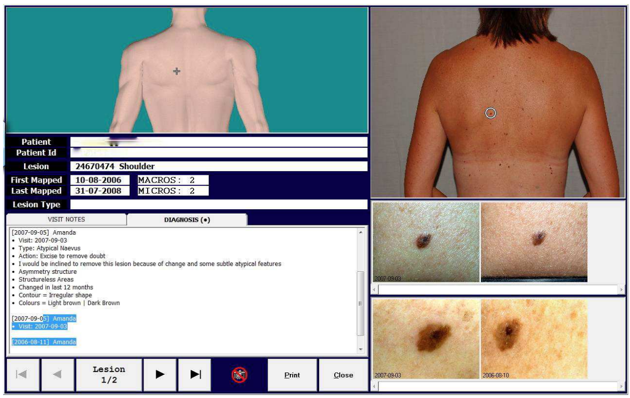

Figure 1. MoleMap diagnosis screen showing sequential dermoscopic images of a thin invasive melanoma.

Skin screening often refers to a visual examination of the whole body; however, it may also be undertaken using whole body photography and digital dermoscopy (Figure 1).

Material and methods

The database of a proprietary whole body photography and sequential digital dermoscopy screening systems for melanoma (MoleMap NZ, Unit L/383 Khyber Pass Road, Newmarket, Auckland, New Zealand) was queried for patients who had histologically confirmed melanoma, or melanoma-in-situ. Demographic and histological details were obtained and compared to similar data of melanoma patients detected by standard methods as reported to the New Zealand Cancer Registry during a ten-year period (Richardson et al. 2008).

Results

There were 52 invasive and 48 in-situ melanomas; 90% were superficial spreading type, 6% were lentigo-maligna type and 4% were nodular on histology. Forty-eight of the melanomas were diagnosed at the first photographic screening and the rest by serial digital imaging. Thirty-five percent of patients reported having had a previous primary melanoma. Sixty percent of the lesions eventually diagnosed as a melanoma had been a concern to the patient, the rest (40%) were detected solely by screening.

Figure 2. Dermoscopy image of an invasive melanoma.

Compared to the NZCR, patients diagnosed by self-referred photographic screening, were younger (age 51 years versus 59) and more likely to be female (54% versus 50%).

Sixty-nine percent of invasive melanomas detected by digital screening had Breslow thickness less than 0.75 mm compared to 52% of NZCR (Table 1). Only one invasive melanoma (1.9%) in the self-referred photographic screening group was thicker than 3 mm (11% NZCR). The average Breslow thickness in an invasive melanoma diagnosed on the first screening visit was 0.87 mm (range 0.30-3.35 mm) but was 0.67 mm (0.22-1.60 mm) when detected by serial monitoring.

Table 1. Breslow thickness of melanoma (number of cases and (%)).

Thickness (mm)	Digital Dermoscopic Screening	NZCR Registrations
0 - 0.75	36 (69.2%)	8,289 (52.3%)
0.76 - 1.49	11 (21.2%)	3,411 (21.5%)
1.5 - 3.0	4 (7.7%)	2,432 (15.4%)
>3.0	1 (1.9%)	1,707 (10.8%)
Total	**52 (100.0%)**	**15,839 (100.0%)**

Discussion

This study shows that screening by whole body photography and sequential digital dermoscopy may detect melanoma at an earlier stage than conventional diagnostic methods, as determined by historical controls from the New Zealand Cancer Registry. These results are similar to those of a number of screening studies. For example, over 90% of melanomas detected clinically during the American Academy of Dermatology national screening programme were in-situ or less than 1.5 mm thick. This was significantly more than that found in their population-based register (Geller et al. 2003, Koh et al. 2006), and this was without widespread use of digital dermoscopy.

Clinical Practice Guidelines in Australia and New Zealand for the Management of Melanoma (2008) do not support population screening for melanoma. However, de-facto screening is taking place in ‘at risk’ patients by general practitioners, dermatologists and other specialists (Youl et al. 2006).

Summary

As survival from melanoma is strongly associated with depth of invasion, we welcome whole body photography and sequential digital dermoscopy screening programmes such as MoleMap. More research is needed to investigate how to encourage patients with thicker melanomas to attend for screening, especially older men.

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Dermoscopic global pattern criteria in practice

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Abstract. New Zealand dermatologists and trainees evaluated standardised macroscopic and dermoscopic digital images of 28 melanocytic skin lesions and 12 non-melanocytic lesions. For each lesion, a single global pattern was selected from 8 choices. Responses were compared to known diagnosis and to self-assessed dermoscopic experience of the participant.

For 11 of the lesions, 4 out of 5 participants selected the same global pattern. These included 3 melanomas with multi-component global features; 6 benign melanocytic lesions with reticular (2), globular, homogeneous, parallel or nonspecific features (1 each); and 2 non-melanocytic lesions with nonspecific features. For 10 lesions, less than half the participants agreed on the same global pattern; 9 were melanocytic naevi and one was subcorneal haemorrhage. Various incorrect features were selected.

Over diagnosis of melanoma was made by 39, 16 and 15 participants in 3 lesions with reticular pattern; by 29, 21 and 22 participants in 3 lesions with nonspecific features; 21 in a starburst lesion; and 20 in a lesion with multicomponent features.

New Zealand dermatologists and trainees find global dermoscopy features are difficult to apply to some skin lesions, irrespective of self-assessed experience of dermoscopy.

Introduction

Dermoscopy is increasingly being used as a tool for diagnosis of melanocytic lesions, including melanoma. Like histology, there is considerable opinion and debate regarding the descriptions and details of specific dermoscopic features and global patterns. The aim of this study was to determine the concordance of dermatologists in the selection of dermoscopic global pattern criteria.

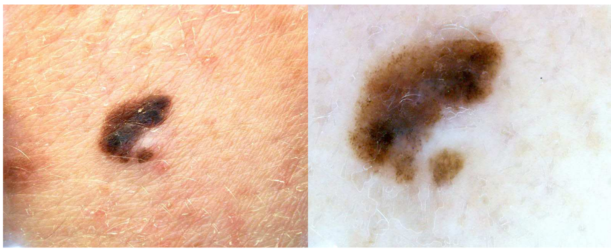

Figure 1. Melanoma showing multicomponent pattern.

Material and methods

As part of an annual audit project of the New Zealand Dermatological Society Incorporated, all New Zealand dermatologists and trainees were required to evaluate standardised macroscopic and dermoscopic digital images of 28 melanocytic lesions and 12 non-melanocytic lesions. For each lesion, a single global pattern was selected from 8 choices. Responses were compared to known diagnosis and to the participant's self-assessed dermoscopic experience.

Results

Although all New Zealand dermatologists took part in the audit, only 39 dermatologists and 6 trainees agreed to their data being used in this study. Self-rated dermoscopic experience was expert (1), experienced (16), confident (19), limited (6), or beginner (3).

For 11 lesions, 4 out of 5 participants selected the same global pattern. These included 3 melanomas with multi-component global features; 6 benign melanocytic lesions with reticular (2), globular, homogeneous, parallel or nonspecific features (1 each); and 2 non-melanocytic lesions with nonspecific features.

Figure 2. Spitz/Reed naevus showing starburst pattern.

For 10 lesions, less than half the participants agreed on global pattern; 9 were melanocytic naevi and one was a subcorneal haemorrhage. Various other global patterns were selected.

Figure 3. Benign naevus showing parallel pattern.

Over diagnosis of melanoma was made by 87%, 36% and 33% of participants in 3 lesions with reticular pattern; by 64%, 49% and 47% of participants in 3 lesions with nonspecific features; 47% in a starburst lesion; and 44% in a lesion with multi-component features.

All four melanomas had multi-component global features, which were recognised by 87%, 80%, 80% and 73% of participants respectively. Other choices were nonspecific (2–20%), reticular (2–7%)), globular (2–4%), homogeneous (0–7%) and lacunar (0–2%). Melanoma was correctly diagnosed by 100% in 2 cases and by 98%

in another. A superficial melanoma with a nodular component was not considered as the primary diagnosis by 11%, even though some had identified multi-component features.

Figure 4. Atypical naevus showing multi-component pattern.

Figure. Combined naevus showing homogenous pattern.

Incorrect global scores correlated poorly with self-assessed experience of dermoscopy.

Discussion

New Zealand dermatologists and trainees find global dermoscopy features are difficult to apply to some skin lesions, irrespective of self-assessed experience of dermoscopy.

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Inter-observer variability of teledermoscopy

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Abstract. To assess the inter-observer variability between teledermoscopists, images from 979 lesions from 206 New Zealand patients were distributed to 5 independent experienced teledermoscopists in New Zealand, Australia and America.

There was excellent agreement between 4 out of 5 teledermoscopists for lesions that were agreed upon as melanoma. The fifth dermatologist made a more frequent diagnosis of melanoma than the others. The agreement for melanocytic lesions was better than that for non-melanocytic lesions: mean kappa values of agreement for benign naevus was K=0.80 and atypical naevus K=0.75, whereas seborrhoeic keratosis K=0.72, BCC K=0.61, solar keratosis K=0.42, SCC-in-situ K=0.24, and invasive SCC K=0.10. There was good ability to distinguish malignant from benign lesions, particularly for basal cell carcinoma.

The Australian/New Zealand dermatologists had good agreement in the diagnosis of melanoma and atypical naevi, which reflects their degree of comfort with their own patient populations. The northern hemisphere dermatologist made a diagnosis of melanoma and atypical naevi more frequently, which may be explained by lack of familiarity with the specific study population. This difference also reflects the lack of consensus guidelines in definition of atypical naevus and possibly diagnostic drift.

Introduction

Teledermatology has evolved through the decades and has been used for various purposes ranging from triage to diagnostics. Teledermoscopy adds epiluminescence microscopy or dermatoscopy to further increase diagnostic accuracy. The purpose of this study was to assess the inter-observer variability in teledermoscopy for the diagnosis of lesions from patients referred by their general practitioner to a lesion diagnosis clinic. External validity was increased by recruiting experienced teledermoscopists from Australia, New Zealand and the United States of America.

Methods

Patients referred to a hospital specialist skin lesion clinic for diagnosis and management of one or more skin lesions were recruited. Panoramic views of the body were first taken to map the location of the lesion(s); followed by macroscopic views (30 mm field of view, ‘macro’) and then dermoscopic views (15 mm field of view, ‘micro’) of the lesion(s). A proprietary software (MoleMap Point of Diagnosis software developed by MoleMap, Unit L/383 Khyber Pass Road, Newmarket, Auckland, New Zealand) was used to manage these files via a remote server, allowing the dermatologists to analyse the data in any location using an authorised computer.

A total of 979 lesions were obtained and the database was distributed to five experienced teledermoscopists, two in New Zealand (A and B), two in Australia (C and D) and one in the United States of America (E).

Lesions that were diagnostically agreed upon by all 5 teledermoscopists were considered the standard of reference to which inter-observer variability was measured. Dermatologist B used the term ‘atypical naevi requiring excision’ for lesions suspect of being melanoma: for the purposes of analysis, these patients were considered in the melanoma group. Pathological data were not used as a comparison as the aim of this study was to assess inter-observer variability, and not diagnostic accuracy, which has been assessed in many earlier trials.

Kappa values were calculated using Stata software (Stata Press, College Station, TX version) to assess the proportion of inter-observer agreement beyond that expected by chance between pairs of observers. Perfect agreement is indicated by a kappa value of 1.0, whereas a kappa value of 0 indicates no agreement at all. We distinguish between the following levels of agreement between observers for the indicated kappa values: poor agreement, <0.20; slight agreement, 0.21–0.40; moderate agreement, 0.41–0.60; substantial agreement, 0.61–0.80; and almost perfect agreement, over 0.81 between observers.

Results

Table 1 shows the distribution of the diagnoses made by the five teledermoscopist. The most common malignant lesion was basal cell carcinoma where up to 80 lesions were diagnosed. The frequency of melanoma diagnosis ranged from 10 to 61. The most common benign diagnoses were benign naevus and seborrhoeic keratosis. The category of “other” included a miscellaneous group of skin conditions including psoriasis, chondrodermatitis nodularis helicis, insect bites, cysts, granulomas, viral warts and sebaceous hyperplasia. Teledermoscopists A–D were uncertain about 2–6 lesions whilst E was uncertain about 42 lesions.

Table 1. Diagnosis made by 5 dermoscopists (A-E).

	A	B	C	D	E
Malignant lesions					
Melanoma	16	10*	22	17	61
BCC	70	61	64	80	73
SCC/KA	24	17	39	12	22
Benign lesions					
SCC-in-situ	24	35	6	11	58
Solar Keratosis	79	97	80	82	39
Seborrhoeic Keratosis	109	89	121	110	92
Benign Naevus	588	592	579	604	92
Atypical Naevus	26	39	28	44	440
Dermatofibroma	5	1	3	3	6
Haemangioma	11	12	13	10	7
Other	21	23	24	4	47
Uncertain	6	3	0	2	42

Teledermoscopists A–D showed substantial degrees of diagnostic agreement amongst one another for the diagnosis of melanoma, with K value over 0.80. Teledermoscopist E varied from the group with the diagnosis of 46 additional melanomas and had a kappa value to 0.38.

Table 2. Kappa values.

	A	B	C	D	E
Malignant lesions	0.84	0.93	0.74	0.85	0.57
Benign lesions	0.46	0.09	0.14	0.07	0.70
Melanoma	0.97	0.85	0.81	0.94	0.38
Benign Naevus	0.10	0.10	0.11	0.10	0.89
Atypical Naevus	0.14	0.09	0.13	0.08	0.
Seborrhoeic Keratosis	0.69	0.80	0.64	0.69	0.78
SCC-in-situ	0.32	0.22	0.3	0.2	0.15
Solar Keratosis	0.38	0.32	0.38	0.37	0.67
BCC	0.61	0.67	0.65	0.55	0.59
Invasive-SCC	0.08	0.11	0.05	0.15	0.09

Teledermoscopist E diagnosed a greater number of additional malignant lesions (109 malignant lesions) above that which was agreed upon by the group. This translates to the lowest kappa value for agreement of 0.57 (Table 2). Accordingly, when kappa statistics were calculated for benign lesions, teledermoscopist E appeared to have the highest kappa score due to the lowest number of additional lesions or lowest deviation from the group. However, when teledermoscopist E was excluded from the analysis, kappa values for the other 4 teledermoscopists rose significantly. Teledermoscopist E also varied significantly from the others in the benign category by diagnosing a greater number of atypical naevi (440 lesions) and fewer benign naevi (92 lesions).

There was more variability in the diagnosis of non-melanocytic lesions, particularly for benign and pre-cancerous lesions such as SCC-in-situ and solar keratosis where the agreement was only slight to moderate (Table 2). There was poor agreement for lesions that were considered invasive-SCC.

Discussion

This study has shown that for melanoma, the diagnostic agreement was generally excellent. It complements the findings from earlier studies on the diagnostic accuracy of teledermatology and teledermoscopy.

The increased diagnosis of melanoma and atypical naevi by one of the teledermoscopists raises important issues for discussion. Several explanations could account for this variability. Firstly, it underscores the difficulty and vagueness in the definition of atypical naevus. It has been defined in the literature as a "naevus with architectural disorder". Despite a consensus conference in 1992, wide variations in the terminology still persist. This variability could be explained by differences in clinical judgment, which is a complex and subjective process.

Familiarity with the study population may play a significant role. The population studied were individuals who were all from 1 centre in New Zealand. Different populations display consistent differences in colour, shape and dimension between their naevi, adding complexities to the definition of atypical. These variations could be accounted for by differences in genetic make-up and environmental factors such as ultraviolet exposure. The Australasian dermatologists (A–D) showed greater consistency in this respect, reflecting their experience of this particular population of naevi.

In addition, clinical judgement and diagnostic threshold is dependent on feedback, both positive and negative, from pathological reports. Pathologists in different parts of the world may over- or under-diagnose melanoma and atypical naevi, which further blurs the distinction between lesions that are classified as atypical/dysplastic versus melanoma. Although pathological diagnosis is often cited as the "gold standard", several reports have documented significant variability amongst pathologists in the diagnosis of melanoma and even more so for SCC. This tendency to either over- or under-diagnose melanoma could lead to a pathological induced 'drift' in clinical diagnosis by the dermatologist. The litigious environment of the USA (or lack of it in New Zealand) may also play a role in diagnostic drift.

Summary

In summary, teledermoscopy shows good agreement for melanoma amongst 4 out of the 5 dermatologists but there is variability between northern and southern hemisphere dermatologists. One of the five teledermoscopists made a diagnosis of melanoma and atypical naevus more frequently, a difference that is likely explained by the lack of familiarity with the specific patient population, lack of consensus guidelines in definition of an atypical naevus, and/or pathologic induced clinical diagnostic drift. There was also more variability in the diagnosis of non-melanocytic lesions.

Inter-observer variability amongst dermatologists is an important aspect for determining clinical accuracy and should be the focus of further research.

Seasonal variation in vitamin D levels and UVB exposure in Christchurch

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Abstract. We measured plasma 25OHD and incident solar UVB radiation in Christchurch during 2004, and modelled the relationship between them. 25OHD (DiaSorin), total calcium (Ca_T) (Aeroset), ionised calcium (Ca_I) (Corning C865) and parathyroid hormone (PTH) (Elecsys) were measured in 201 healthy volunteers (median age 45 yrs, range 18 to 83) between February and July 2004. Vitamin D-weighted (Maclaughlin) UV energy measurements (dUV) for Christchurch were from the NIWA UV Atlas. In February, 88% of 25OHD levels were below 75 nmol/L, increasing to 100% in June and July. Severe deficiency (<12.5 nmol/L) was found in 1.5% of subjects. From February to July, 25OHD and Ca_I fell and Ca_T rose (all p <0.001). No correlation was found between 25OHD and PTH, but Ca_T and Ca_I correlated negatively with PTH (both $p < 0.001$). Monthly mean dUV intensity ranged from 10 kJ·m^{-2}·day^{-1} in Dec 2003 to 0.5 kJ·m^{-2}·day^{-1} in Jun 2004. Compartmental modelling estimated that a Christchurch person made 1200 IU/day of vitamin D in mid summer but only 60 IU/day in mid winter. Daily supplements of 1800 or 2900 IU vitamin D_3 are predicted to raise the annual minimum average plasma 25OHD to 75 or 100 nmol/L respectively

Introduction

It has been proposed that the optimal plasma concentration of 25-hydroxyvitamin D_3 (25(OH)D) should be at least 75 nmol/L (Bischoff-Ferrari 2006, Vieth 2007). This figure is based on observational evidence relating 25(OH)D levels to the risks of fracture, periodontal disease, colorectal cancer and lower-extremity muscle weakness. Within New Zealand, a survey of the Auckland workforce found that a large proportion of the workers, if not the majority, had serum 25(OH)D concentrations below 75 nmol/L (Scragg 1995). In a survey of New Zealanders aged 15 years and older, 3% were considered to have frank deficiency (less than 18 nmol/L) and 48% insufficiency, based on a cut-off of 50 nmol/L (Rockell 2006), and with differences apparent due to age, gender, latitude and season. We now report the relationship between plasma 25(OH)D levels and solar UV in the general adult population in a southerern New Zealand location. We also model predictions of vitamin D metabolism to assist in the effective remediation of poor vitamin D status.

Methods

Volunteer subjects (n=201) were residents of Christchurch, New Zealand (44^o S), recruited from electoral rolls or advertisement to a study to establish reference intervals for endocrine test methods. They completed a questionnaire and were accepted if aged 18 or over, considered themselves healthy and did not meet

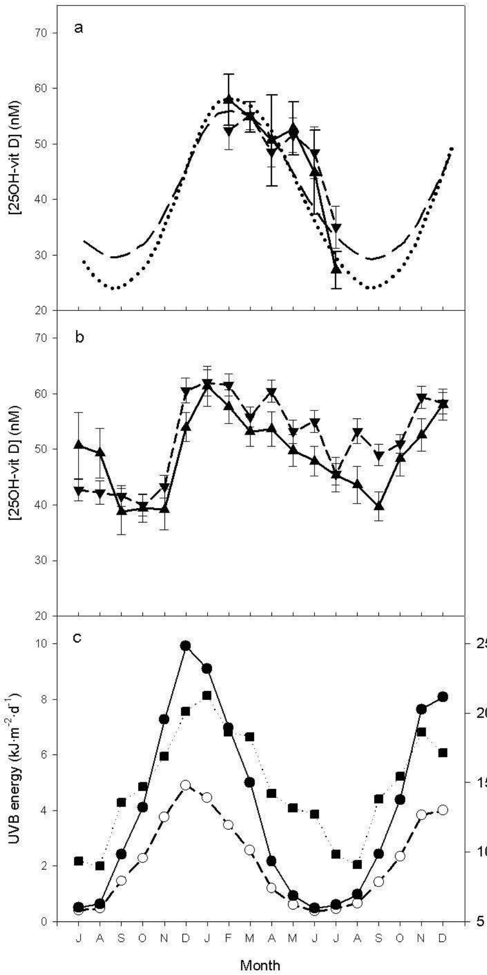

Figure 1. Monthly plasma 25-hydroxy vitamin D concentrations in male and female Christchurch residents (mean±sem) for (**a**) the volunteer group and (**b**) the patient group. ▲——▲ male; ▼——▼ female. The smooth dashed line in **a** is the prediction of the best-fit model (dietary vitamin D 350 IU/d), and the dotted line shows the best fit if dietary vitamin D is assumed to be 200IU/d. Panel **c** shows the corresponding monthly means of the UVB energy received daily at ground level and the maximum daily temperature. The first month is July 2003 and the last December 2004. ●——● dUV; ○ - - - ○ eUV; ■ · · · ■maximum temperature.

exclusion criteria that included diabetes and endocrine conditions, relevant cancers, steroid medication and recent hospitalisation. A single morning blood sample was collected between February and August 2004 from 209 individuals of whom 105 were fasting. After excluding those who did not meet the above criteria or who were taking vitamin D supplements or cod-liver oil, 25(OH)D measurements were available for 201 volunteers. Mean (±sd) age was 46±14 years with a median of 45 years (range 18 to 83) and the mean (±sd) body mass index was 26.3±4.7.

The patient group came from within the Christchurch region from whom samples were submitted for measurement of plasma 25(OH)D between 1 July 2003 and 31 December 2004. It comprised 3702 samples from females and 1138 from males, with a mean (±sd) age of the whole group of 59±23 years and a median age of 63 years (range 0.1 to 101). Samples were submitted from hospital wards, outpatient clinics and private practices. It is not known how many patients were taking vitamin D supplements.

25(OH)D was measured using the DiaSorin radioimmunoassay kit (Stillwater, MN, USA). The low, medium and high QC values with coefficients of variation are 16.5 (16.2%), 35.9 (7.8%) and 132 (7.8%) nmol/L.

Plasma calcium was measured on the Abbott Aeroset analyser (Abbott Laboratories, Abbott Park, IL, USA) by colorimetry using the Arsenazo-III dye method (intra-assay CV 0.8% at 3 mmol/L). Serum ionised calcium was measured on the Corning C865 blood gas analyser (Ciba Corning Diagnostic; Medfield, MA, USA) by calcium ion-selective electrode (between-batch CV 1% at 1.22 mmol/L). Parathyroid hormone (PTH) was measured using the Roche Elecsys 2010 system. The low, medium and high QC values with coefficients of variation are 2.2 (6.9%), 8.2 (5.3%) and 31.5 (4.7%) pmol/L for PTH and 0.46 (7.5%), 0.59 (10.4%).

Daily UV irradiances (W/m^2) at one hour intervals were taken from the NIWA UV Atlas software package (http://www.niwascience.co.nz/services/uvozone/atlas). The irradiances for Christchurch were summed to give the mean for each month of total erythemally-weighted UV (eUV) and vitamin D-weighted UV (dUV) per day.

Results

Plasma 25(OH)D tended to rise as UVB energy rose in spring and to fall as UVB energy fell in autumn (Figure 1). The 25(OH)D levels tended to lag behind UVB. The large majority had below optimal levels (below 75 nmol/L) regardless of the time of year and the majority showed insufficiency (below 50 nmol/L) in June, July and August. Frank deficiency (less than 25 nmol/L) was evident in at least a few individuals in each month studied and rose to 35% of the volunteer group in July-August. Only 1.5% of the volunteers had 25(OH)D below 12.5 nmol/L (one person in May and two in July). As the year progressed, 25(OH)D levels fell ($p < 0.001$), total calcium rose ($p < 0.001$) and ionised calcium fell ($p < 0.01$, $p < 0.001$). PTH levels were neither significantly correlated with time of year nor with 25(OH)D levels. The quantity of supplemental vitamin D needed to raise the modelled annual minimum plasma 25(OH)D in the volunteer group to 75 nmol/L is predicted to be 1800 IU/d (45µg/d), or to raise it to 100 nmol/L, 2900 IU/d (73 µg/d). On the other hand, if year-round sunlight exposure were to be doubled, in the absence of supplementation, the annual maximum plasma 25(OH)D is predicted to rise from 56 nmol/L to 80 nmol/L and the annual minimum to rise from 29 nmol/L to 37 nmol/L.

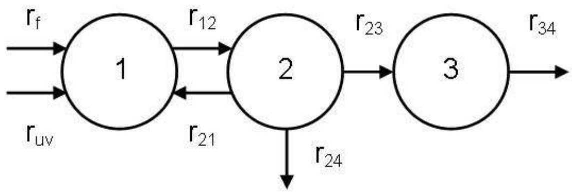

Figure 2. Model of vitamin D metabolism. Compartments 1 and 2 contain vitamin D_3 and compartment 3 contains 25(OH)D; 4 denotes further (undefined) metabolites. Rates (nmol/day) are denoted r and rate constants k. Parameters α and β define the feedback of 25(OH)D on its production rate. r_f = dietary vitamin D_3, $r_{uv} = k_{uv}\,E_{uv}$, E_{uv} = dUV energy, $r_{12} = k_{12}c_1$, $r_{21} = k_{21}c_2$, $r_{24} = k_{24}c_2$, $r_{23} = k_{23}c_2 = c_2\alpha/(1+\beta c_3)$, $r_{34} = k_{34}c_3$.

Discussion

The two principal findings of this study are firstly that most, if not virtually all, of the apparently healthy general population in Christchurch do have not adequate circulating levels of 25(OH)D at some time during the year, and secondly that relatively high levels of supplementation with vitamin D would be required to achieve healthy concentrations of 25(OH)D year round.

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