Vitamin D Irradiance in Summer Shade and Sun:

Vitamin D and summer sun exposure at mid latitudes for the Northern and Southern Hemispheres

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Main points (extrapolated sentences)

UV radiation is known to cause skin cancer and eye disorders; however, it is extremely important for the production of vitamin D in humans.

Utilising shade for vitamin D exposures can reduce total UV exposure by up to 60% compared to full sun exposures.

Research indicates that an improved approach to optimise UV exposures for vitamin D production is to utilise scattered UV under shade in and around the middle of the day.

Abstract
Past research has shown that certain shaded environments (e.g. shade umbrellas, gazebos, patios) can be used to obtain the necessary levels of UV exposure for the synthesis of vitamin D. This paper discusses the levels of solar ultraviolet radiation during summer at specific mid latitudes in the Northern and Southern Hemispheres and how this relates to the physiologic production of vitamin D in the human body. Specifically, the sites of London (UK) and Hobart (Australia) are utilised. It was found that in summer at these mid latitudes vitamin D synthesis could be initiated in as little as 2 minutes in full sun and 6 minutes when in the shade.

Introduction

UV radiation is known to cause skin cancer and eye disorders; however, it is also extremely important for the production of vitamin D in humans. The main function of vitamin D in humans is to maintain concentrations of calcium and phosphorous in the human body (1). Numerous studies have indicated that low vitamin D levels in the blood are linked to a number of diseases and disorders including breast cancer, prostate cancer, colorectal cancer, multiple sclerosis, non-Hodgkin's lymphoma, inflammatory bowel disease, diabetes, bacterial infections, elevated cholesterol, rheumatoid arthritis, rickets, osteoporosis, osteomalacia, and fractures in the elderly (2,3). It has been estimated that around 85,550 premature deaths occur each year in the USA from cancer due to insufficient vitamin D (4). The simplest way to obtain vitamin D is from moderate sun exposure (2). Small amounts of vitamin D can be obtained from certain foods and vitamin tablets; however, it has been shown that the vitamin D from these sources cannot provide sufficient vitamin D for the elderly (5).

Australia and Canada have guidelines illustrating how much UV exposure the public should receive for vitamin D synthesis. However, few other countries have any such guidelines. The Australian guidelines suggest exposure to approximately 1/6 to 1/3 of a minimum erythemal dose (MED), which is equivalent to approximately 34-67 Jm^{-2} of UV radiation, would be appropriate to provide adequate vitamin D levels (6,7). This is also dependent on age and skin colour with exposure levels needing to be increased for older populations and those with darker skin (8-11). The Working Group of the Australian and New Zealand Bone and Mineral Society, Endocrine Society, Osteoporosis Australia, Australian College of Dermatologists and the Cancer Council Australia recommend five minutes solar UV exposure either side of the peak UV periods on most days of the week in summer and approximately 2-3 hours solar UV exposure over a week in winter (12).

UV radiation is incident on the earth's surface in the two distinct components of direct and scattered. The direct component travels in a straight path from the sun and can be easily blocked by shade structures. A large proportion of the incident radiation also interacts with atmospheric constituents and becomes the scattered component. This scattered component is then incident on humans from all directions and is much more difficult to block. Past studies (such as 13-18) have indicated that humans can still receive significant UV exposures beneath shaded environments due to atmospheric scattering. Atmospheric constituents cause greater scattering to occur at the shorter UVB (280-315 nm) wavelengths than at the longer wavelength UVA (315-400 nm). Consequently, in the shade there is an increase in the relative proportion of the biologically effective UV wavelengths (290-330 nm) associated with the physiologic production of vitamin D in the body and a decrease in the total UV exposure compared to full sun.

UV minimisation strategies rely on many different elements with one specific component being the use of shade environments such as shade umbrellas, gazebos, patios, trees, etc. Recent research (13-15,18) shows that shade settings may also play a key role in assisting with exposures to the human body related to vitamin D synthesis without experiencing the higher levels of total UV experienced in full sun.

Results and Discussion

Full sun and shade exposures

The variation in vitamin D effective UV (UV_{D3}) irradiances, for full sun and shade, for relatively clear sky conditions and a changing solar zenith angle (SZA) is shown in Figure 1. The field measurements from each of the latitude sites has been averaged for the two separate groups of: full sun; and shade (a sky view $\geq$ 40%). Sky view refers to the amount of sky that can be seen by the observer when situated beneath a shade environment. A sky view of approximately 40% can be obtained by being positioned near the edge of the shade cast by the shade structure. For a SZA of approximately 20^o, the average UV_{D3} irradiances were 0.63 W/m^2 and 0.19 W/m^2 for full sun and shade respectively. For the larger SZA of approximately 60^o, average UV_{D3} irradiances for full sun and shade were 0.17 W/m^2 and 0.07 W/m^2 respectively.

Exposure times for 1/3 of a minimum erythemal dose (MED)

The average times for an exposure equivalent to 1/3 of a MED for vitamin D are shown in Table 1 for full sun and shade. For a SZA of 20^o, the average time needed to receive an exposure of 1/3 of a MED was 1.8 and 5.7 minutes for full sun and shade respectively. For the larger SZA of approximately 60^o, the average time for exposure in full sun and shade was approximately 6.5 and 15.9 minutes. The times provided in Table 1 are based on exposing 15% of the human body (face, neck and hands) to UV radiation. Increasing the exposed body surface will subsequently decrease the time needed for vitamin D production (e.g. exposing four times more body surface will reduce the exposure times presented in this research by a factor of 4). Even the older populations and those with highly pigmented skin should be able to synthesise vitamin D in the shade.

Experimental

Shade structures and latitudinal field measurements

Measurements were conducted beneath numerous shade structures to investigate the influence of a number of different factors, namely sky view, cloud cover and solar zenith angle. A portable spectrometer (model USB4000, Ocean Optics, USA) was employed to measure the solar UV radiation spectrum both outside and inside the shade. Further details of the system are described elsewhere (18). The shade environments were chosen so a range of differently sized and shaped shade environments with different sky views could be investigated.

Spectral UV field measurements were conducted over a two week period during summer at each site of:

London - August 2008 (lat 51^o 30’ N; long 0^o 05’ W)
Hobart - December 2008 (lat 42^o 52’ S; long 147^o 19’ E)

Spectral measurements were gathered throughout the day to account for the change in solar zenith angle. The measurement protocol consisted of measuring the full sun spectral irradiance for the horizontal and sun normal planes in full sun, followed by measurement of the spectral UV in the shade for the horizontal, 45^o and vertical planes (the 45^o and vertical measurements were directed to the north, south, east and west). Measurements in the shade were conducted at: different distances from the edge of the shade cast by the structure depending on the level of sky view being observed. The level of sky view was separated into two distinct groups of (i) a sky view $\geq$ 40% (light shade) and (ii) a sky view < 40% (deep shade). For simplicity, only light shade observations are discussed in this paper as deep shade is of no benefit. The sky view levels were estimated through observations and also the use of a convex mirror that was placed in the shade.

Conclusions

Solar UV is incident on the earth in two distinct components of direct and scattered. The direct component is virtually unhindered on its path through the atmosphere; whereas the scattered component is affected by atmospheric scattering. Many studies have looked at how direct UV radiation interacts with humans in regard to the detrimental and beneficial effects. UV protection is very important and many strategies can be adopted to reduce overall UV exposure including the use of sunscreen, shade, hats, appropriate clothing and sunglasses. However, the constant use of UV protection may lead to a vitamin D deficiency. Currently, there is a major gap in knowledge in order to optimise the beneficial effects related to vitamin D effective wavelengths compared to reducing the biologically damaging overexposure to UV radiation.

Variations in cloud cover are far less likely to cause an obvious change in UV_{D3} exposure times in the shade; whereas full sun UV_{D3} exposure times will vary significantly depending on cloud cover and solar disc cover. Shade with a sky view of greater than 40% can be found very easily and this makes it very useful for the general public as the damaging UVA wavelengths are reduced more on a relative basis compared to the beneficial vitamin D effective wavelengths. Utilising shade for UV_{D3} exposures can reduce total UV exposure by 37% to 58% compared to full sun UV_{D3} exposures (18). The best time to expose the human body to UV radiation while utilising shaded environments with a sky view of greater than 40% for vitamin D synthesis is for SZAs less than approximately 50^o (for example, sitting near the edge of the shade cast by a shade umbrella for 5-10 minutes between the times of 9:00 AM and 3:00 PM in summer). Shade can be used throughout different latitudes during summer. This research indicates that an improved approach to optimise UV exposures for the production of vitamin D is to utilise scattered UV under shade structures in and around the middle of the day. However, UV protection is still extremely important when in the sun or shade for extended periods of time.

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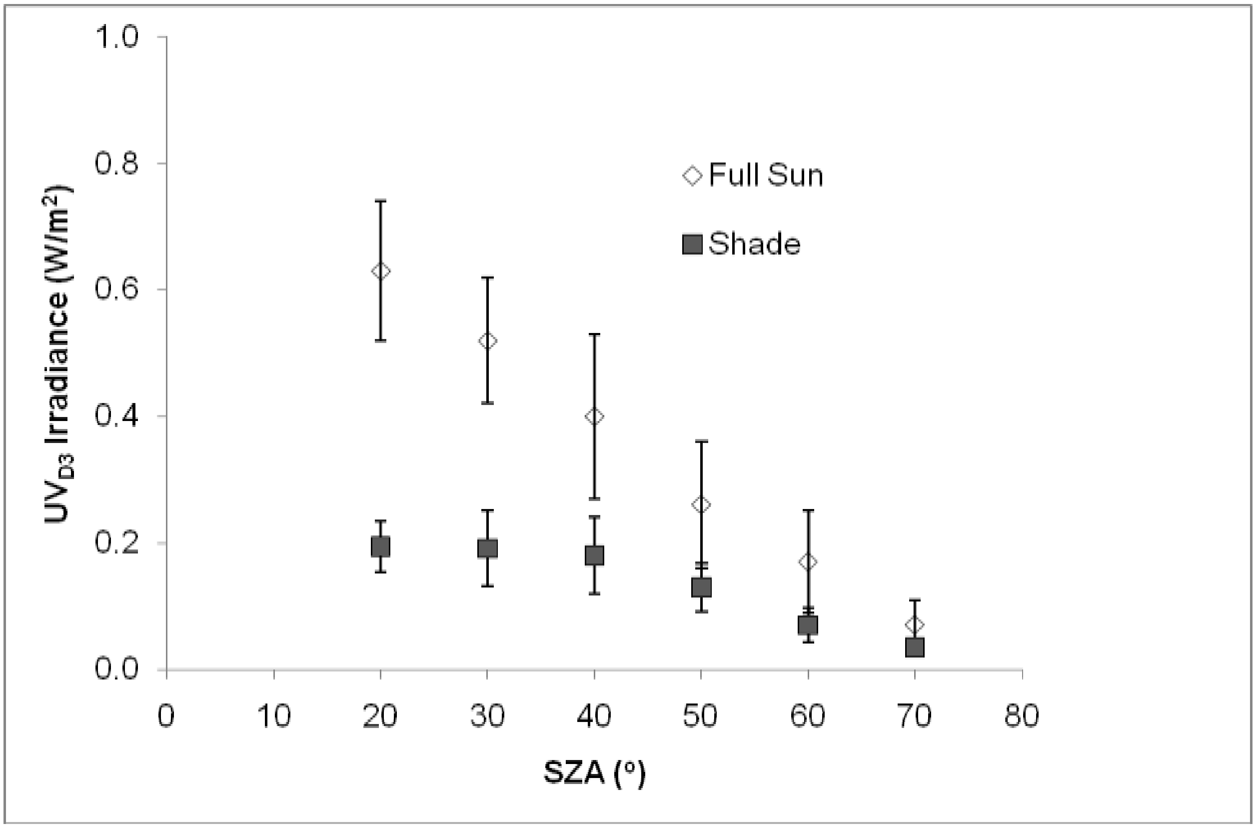

Figure 1. Variation between full sun (◊) and shade (■ for a sky view ≥40%) for UV_{D3} irradiances during relatively clear sky conditions. The error bars are ± one standard deviation of the data for each data point.

Table 1. Average times for both sites for exposure to UV levels in full sun and shade for adequate vitamin D production. The standard error (as a percentage) is provided in the parentheses. These exposure times are for Skin Type II and will increase for more pigmented skin. A SZA of approximately 20^o to 50^o will be observed between the times of 9:00 AM and 3:00 PM during summer at these sites.

	Full Sun	Shade
SZA (^{o})	Time (minutes)	
20	1.8 (17)	5.7 (21)
30	2.1 (19)	5.8 (31)
40	2.8 (33)	6.2 (33)
50	4.3 (38)	8.6 (29)
60	6.5 (47)	15.9 (40)
70	15.9 (57)	31.8 (34)