Sun exposure, shade and vitamin D: a practical activity for the Australian climate and curriculum

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Australia has one of the highest rates of incidence and mortality due to skin cancer in the world. Exposure to the sun also has a beneficial side. The beneficial effects are relatively few, but they are essential to a person's well being. It is well known that exposure to small amounts of UV radiation are beneficial for the human body and important in the production of vitamin D_3. This investigation will give students the opportunity to measure erythemal UV radiation in full sun and in the shade to determine how this can be potentially beneficial. An important outcome of this investigation will be to illustrate that some exposure to sunlight is necessary for long-term human health.

It is well known that excessive and repeated exposures to solar UV radiation are linked to the induction of skin cancers, skin damage, premature skin ageing and wrinkling, and sun related eye disorders (van der Leun and de Gruijl, 1993; NHMRC, 1996). Australia has one of the highest rates of incidence and mortality due to skin cancer in the world, with two out of three Australians developing some form of skin cancer in their lifetime (Giles et al, 1988; ACCV, 1999). UV radiation in the 290 to 330 nm portion of the terrestrial solar UV spectrum breaks down 7-dehydrocholesterol in human skin to pre-vitamin D_3. Pre-vitamin D_3 is then converted to vitamin D_3 by a heat induced process in the human body. The main function of vitamin D_3 in humans is to maintain extracellular fluid concentrations of calcium and phosphorous (Holick, 1997). Small amounts of vitamin D_3 can be obtained from vitamin tablets and certain foods; however, these sources cannot provide sufficient vitamin D_3, particularly for the elderly (Mosekilde, 2005). The most cost effective and simplest way to obtain vitamin D_3 is from moderate exposure to sunlight (Holick, 2004).

At present, Australia is amongst a small handful of countries that have guidelines on how much UV exposure the public should receive for vitamin D_3 synthesis. The Australian guidelines advise exposure to approximately 1/6 to 1/3 of a MED as appropriate to provide adequate vitamin D_3 levels, depending on the age of the individual (Samanek et al, 2006; CDHAA, 2006). The minimum erythemal dose (MED) is equivalent to approximately 200 J/m^2 of erythemally effective solar UV radiation, depending on the skin type of the individual which can be broadly defined into six categories (Fitzpatrick, 1975). Approximately 1/6 to 1/3 of a MED is represented by 34-67 J/m^2 of erythemally effective solar radiation. The erythemal (sunburn) response of humans to UV radiation is given by the erythemal action spectrum (Figure 1). A UV meter can be used to approximate the erythemally effective solar radiation.

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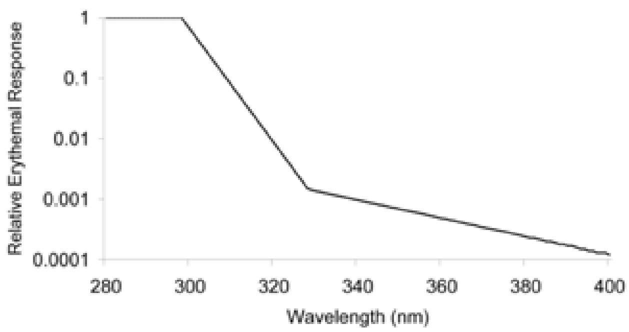

Figure 1. The human erythemal action spectrum (CIE, 1987). The normalised relative effectiveness of the UV spectrum to cause sunburn.

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 (PS, 2006).

This investigation will give students the opportunity to measure erythemal UV radiation in full sun and in the shade to determine how this can be potentially beneficial. An important outcome of this investigation will be to illustrate that some exposure to sunlight is necessary for long-term human health. Shaded environments are environments that can mediate the harmful effects of the sun depending upon the quality of the shade and the amount of sky that can be seen in the studied location.

Materials and Methods

The following is required to perform this activity:

A hand-held UV meter that uses specific filters to approximate the human erythemal response (CIE, 1987). A cost effective model is the Edison Pocket UV Meter (Figure 2) available online at http://www.dealsdirect.com.au/p/pocket-uv-meter/ at a cost of approximately AU$30.

Figure 2: The Edison Pocket UV Meter.

Warning: This investigation will require students to spend extended periods outdoors. Use appropriate sun protection strategies such as sunscreen, hats and sunglasses to reduce personal UV exposures.

Pick three or four different commonly used shade environments such as a shade umbrella (Figure 3), dense tree shade or gazebo. Choose a cloud-free day (or cloud free solar disc) for this investigation. To investigate the effect of the different angles of the sun on the UV radiation in the shade and the resultant vitamin D exposure times, take the following measurements at different times of the day.

To measure the UV:

1. Measure the full sun UV irradiance on a horizontal plane (with the hand-held radiometer directed upwards) at a distance of at least 20 m or as far as possible from any shade.
2. Measure the UV in the shade at a height of approximately 1.2 m with the UV meter inclined along the horizontal, 45°, and the vertical plane. (The 45° and vertical measurements are best performed by directing the radiometer to where the most sky can be seen.)
3. Immediately after finishing the shade measurements, measure the UV in the full sun as far away from any shade as possible.
4. Repeat the measurements for different times of the day (e.g. 9am, 10:30am and 12 noon). This will ensure that several solar positions or zenith angles will be tested. (The term Solar Zenith Angle (SZA) is often used to denote solar position and represents the angle subtended between the solar disc and the zenith.)
5. Repeat the measurements for the other shade environments.
6. Repeat the investigation on another day when the Sun is covered by cloud (optional).

To calculate exposure times, *t*, for 1/3 MED use the following equation:

$$t_{mins} = \left(\frac{1/3 \times MED}{I}\right)/60 \qquad (1)$$

where a *MED* is equal to 200 J/m² and I is the irradiance measured by the pocket UV meter (radiometer) in W/m² (or J/s¹/m²). Here, 200 J/m² is used for a *MED* as this represents the exposure required to cause perceptible erythema for skin type 1.

The SZA for any latitude and longitude can be obtained from the following website: *http://www.usno.navy.mil/USNO/astronomical-applications/data-services/alt-az-world*


Figure 3: Shade umbrella in the yard.

Results and discussion

Table 1 shows a sample of results obtained on a relatively clear sky day during December 2007 at the University of Southern Queensland. As can be seen in Table 1, 1/3 of a MED can be obtained in a relatively short period of time in full sun. Due to atmospheric scattering, a significant amount of UV radiation can be found in the shade. Therefore, shade environments can also be used to expose the human body for adequate vitamin D production. However, exposure times will be slightly longer than for full sun environments. The sample results show that exposures in the shade are generally twice as long for SZA positions of around 35° or less compared to full sun.

	FULL SUN		SHADE	
SZA (°)	W/m²	min	W/m²	min
5	0.25	4.4	0.12	9.3
15	0.21	5.3	0.11	10.1
25	0.18	6.2	0.09	12.3
35	0.15	7.4	0.07	15.9
45	0.10	11.1	0.06	18.5
55	0.05	22.2	0.04	27.8

Table 1: Sample of results for a shade structure showing erythemal UV levels beneath a shade umbrella (see Figure 3) and in full sun, with calculated times (in minutes) for exposure to 1/3 of a MED.

The times calculated in Table 1 are based on exposing 15% of the human body (face, neck and hands) to UV radiation. Samanek et al (2006) states that high variability in sun exposure times during winter means that optimal sun exposure advice should be tailored to each location. Therefore, this experiment can be conducted in winter to give students a better idea of how exposure times will vary depending on season. Also, the more sky that can be seen in the shade produced by the shading structure means the more scattered UV radiation there is incident in the shaded area. So a range of different sized shade structures may be useful in showing students how the sky view will change the exposure times. 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, a small amount of sun exposure is needed for optimal health. This article details techniques that provide students with the opportunity to study the physics of electromagnetic radiation, particularly UV radiation, and the way it interacts with different environments.

The investigation is therefore suited to studies of the environment and our place within the environment. Currently such an investigation is well suited to the *Earth and Beyond*, and *Science and Society* strands of various state curricula in both primary and secondary schools. The task described also compliments extended experimental investigations as it can be performed over a long investigation period for many different seasonal, diurnal and atmospheric conditions. The experiment can also be performed to assess the potential health benefits of different shading environments. Nationally, such an investigation is relevant to the strands *science understanding* and *science inquiry skills* presented in the Interim National Curriculum Board's (NCB) foundation document for the recently released draft of the Australian curriculum for science (NCB, 2009). More specifically, the proposed vitamin D activity develops the opportunity for students to explore current health and prevention research relevant to contemporary science, a key term presented in the new Australian curriculum for science (NCB, 2009). By completing the proposed activity students get the opportunity to study solar radiation as a form of energy, develop links between the physical environment and its potential to impact upon human health, and build upon existing data collection and analysis skills. These skills are critical elements, necessary for the development of quality foundation courses in science and are clearly identified in the primary and middle school years of the new Australian curriculum.

Recommended Reading:

Samanek, A.J., Croager, E.J., Gies, P., Milne, E., Prince, R., McMichael, A.J., Lucas, R.M. & Slevin, T. (2006). Estimates of beneficial and harmful sun exposure times during the year for major Australian population cities. *Medical Journal of Australia*. 184, 338-341.

Position Statement (PS). (2006). Estimates of beneficial and harmful sun exposure times during the year for major Australian population centres. *Medical Journal of Australia* 184, 338-341.

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