Effects of Solar Altitude -vs- Artificial Spectra on Vitamin D & Erythema

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ABSTRACT

Vitamin D production in human skin is a beneficial effect of sunlight exposure. In this study we examine the vitamin D effectiveness spectra of sunlight at various solar altitudes and compare these results with several clinically available sources.

At the latitudes of Boston and points north, there is insufficient UVB from low angle sunlight to produce adequate vitamin D for several months each year. Populations in northern latitudes benefit from dietary vitamin D supplementation. In individuals with limited intake or utilization of dietary vitamin D, supplemental U prescribed.

Supplemental UV exposure must include sufficient UVB radiation to produce the required phototransformation of 7-dehydrocholesterol to pre-vitamin D. While all sources emitting UVB can produce Vitamin D in human skin, emission of UVA or UVC can make using some sources less desirable because of additional confounding effects.

Our survey suggests that a simple filtered intermediate pressure mercury source may be optimal for home or clinical Vitamin D therapy.

METHODS

Solar spectra were collected in Kuwait City at the Al Sabah Hospital using an Optronic Laboratories OL-742 Spectroradiometer. Spectra were collected from 260 nm to 400 nm in 2 nm increments and stored on magnetic media. The spectroradiometer was cooled and protected from the heat when not in use. See Figure 1 for measurements.

Spectra of two additional sources were obtained by measuring those sources at normal use distance. Because these sources may have spectral lines present, they were measured at 1 nm increments (Figure 2). The additional sources are the SPERTI PH 36 Phototherapy unit and a Daavlin 8 bulb PUVA/Tanning Unit. The bulbs in this unit are standard 2.5% UVB PUVA bulbs which are similar to bulbs used in some indoor tanning units.

Spectral Analyses were performed by multiplying each solar spectrum with either the CIE erythemic action spectrum or a vitamin D3 response spectrum1 (Figure 3). The resulting effectiveness spectra, summed over contributing wavelengths, is expressed as effective irradiance (W/cm2).

The ratio of Vitamin D3 effective irradiance divided by the Erythemic irradiance rate is an index of benefit to risk. The higher this index the greater the relative D3 benefit -vs- risk of injury from the exposure. The lower the index the greater the risk of sunburn.

RESULTS

In all 166 solar spectra, collected over 7 months, were analyzed. The solar altitudes examined were from –10º to 80º, approximately the maximum altitude near 30º North latitude. Spectral comparison of sunlight at various solar altitudes (Figure 1) shows that as solar altitude decreases the relative proportion of shorter

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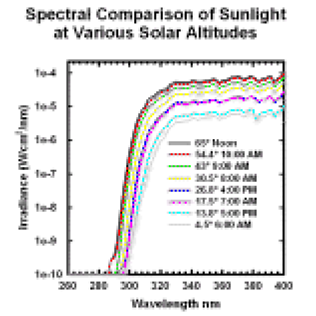
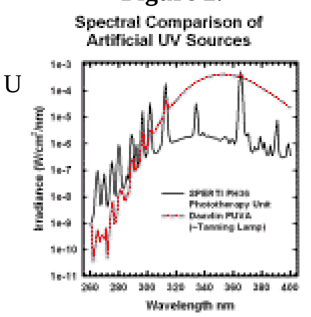
Figure



1.

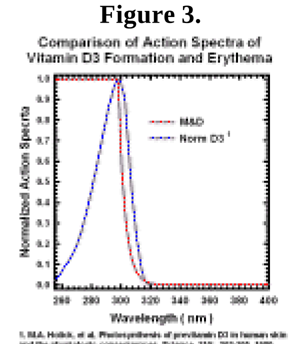
Spectral comparison of sunlight at various solar altitudes shows that as solar altitude decreases the relative proportion of shorter wavelength UVB radiation also decreases.

Figure 2.



Spectral comparison of these artificial UV sources shows the relative contribution of UVB and UVA radiation available from these lamps.

Figure 3.



The erythemic response spectrum extends over 4 orders of magnitude from 290 - 400 nm. The Vitamin D3 response spectrum ranges over 2 orders of magnitude from 290 - 320 nm. In fact the response would appear to be 0 at wavelengths beyond 320 nm.

Figure 4.

wavelength UVB radiation also decreases.

Intraday calculations show how the vitamin D3 effective irradiance and the erythemic effective irradiance change throughout the day as a function of solar altitude. Both vitamin D3 effective irradiance and erythemic effective irradiance peak around local solar noon and drop off significantly with decreasing solar altitude (Figure 4). As expected most of the erythemic risk occurs between 10 AM and 2 PM. However for several hours in the morning and evening the vitamin D effective irradiance is not significantly different from the erythemic effective irradiance.

When all data sets were combined the effect of low solar angle on the vitamin D production relative to erythema becomes more apparent (Figure 5). For solar spectra measured below 30º altitude, the two effective fluence rates are essentially equivalent. Above 30º the vitamin D3 effective irradiance is greater than the erythemic effective irradiance.

For each spectrum measured, the ratio of vitamin D effective irradiance divided by erythemic effective irradiance shows the relative benefit to risk ratio (Figure 6). The higher this index the greater the relative D3 benefit -vs- risk of injury from the exposure. The lower the index the greater the risk of sunburn. At high solar elevations the ratio favors vitamin D formation. At lower solar altitudes, it may be impossible to form vitamin D without sunburning depending on the amount of skin surface exposed.

His ratio for the two artificial sources shows how they compare to the various solar altitudes (Figure 6). Note the standard Tanning/PUVA unit has a lower ratio than does the SPERTI PH 36 Phototherapy unit. The spectral comparison of these artificial UV sources (Figure 2) shows the relative contribution of UVB and UVA radiation available from these lamps.

DISCUSSION

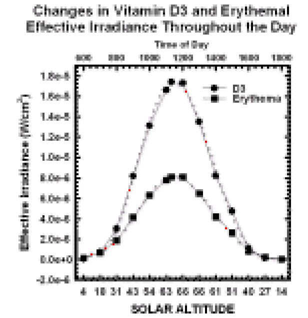
Our work suggests that when the sun is low in the sky (early or late in the day or in the winter) the production of Vitamin D3 will be limited by the length of exposure time needed and by the occurrence of sunburn. In the summer, when the sun is high in the sky, little exposure will be required to produce Vitamin D3, less than required to produce sunburn. These results contradict current wisdom about sunlight exposure.

However, one caveat needs to be considered. The erythemic response spectrum was developed and validated in ~20 laboratories. The Vitamin D3 action spectrum is based only on the work of a single laboratory. A small change in the wavelength or energy to produce Vitamin D3 could significantly alter the interpretation of solar and other spectra. The erythemic response spectrum extends over 4 orders of magnitude from 290 – 400 nm. The Vitamin D3 response spectrum ranges over 2 orders of magnitude from 290 - 320 nm. In fact the response would appear to be 0 at wavelengths beyond 320 nm.

Our literature search for quantitative studies on vitamin D3 production was disappointing. We could not find quantitative data on D3 produced per square centimeter of skin irradiated with either monochromatic or polychromatic UV. While the literature suggests that aged skin is less effective at producing D3 than younger skin, no data was found to substantiate this. In the literature, it is claimed that the cheeks of children outdoors produces all the D3 they require, yet no details on solar elevations or exposure times or actual skin surface area irradiated were found.

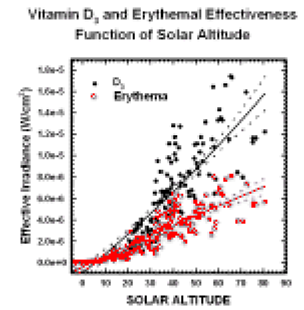
Current consumer advice suggests that protective sunscreens SPF 15 or higher should always be worn. Our review of the literature indicates that sunscreens block formation of vitamin D. Our work in this study suggests that any diminution of the available UVB radiation is contradicted for production of vitamin D.

At latitudes where the solar altitude is low for much of the year, excess clothing may be required for protection from the climate. This reduction in exposed skin surface further diminishes the natural production of vitamin D, underscoring the potential benefits of supplemental UV exposure.



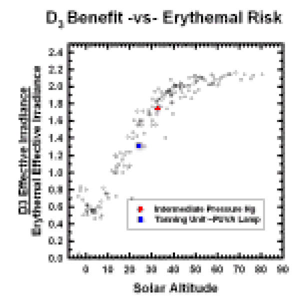
Vitamin D3 effective irradiance and erythemic effective irradiance change throughout the day. Both peak around solar noon and drop significantly with decreasing solar altitude. Most erythemic risk occurs around midday but, for several hours each morning and evening vitamin D effectiveness is not different from erythemic risk.

Figure 5.



Vitamin D3 effective irradiance and erythemic effective irradiance for each solar spectra measured. Below ~30° altitude, the effectiveness is equivalent, while above 30° the vitamin D3 effectiveness is greater than the erythemic risk.

Figure 6.



The benefit to risk ratio, vitamin D effective irradiance divided by erythemic effective irradiance, of all spectra measured. At high solar elevations the ratio favors vitamin D3 formation. At lower solar altitudes, it may be impossible to form Vitamin D without sunburn. Of the two artificial sources shown the UVA Tanning/PUVA lamp has a lower ratio than does the UVB SPERTI PH 36 Phototherapy unit.

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