Availability of Vitamin D UV and a "Vitamin D index" for public UV exposure advice

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Abstract. Vitamin D production in the skin by UV exposure is the most promising means of alleviating the worldwide burden of vitamin D deficiency. However, we demonstrate that Vitamin D production cannot be quantified by the current UV Index, which is based on the erythemal action spectrum. Large disagreement was observed when comparing (by computer simulation) the daily levels of erythemal UV and UV weighted for the established vitamin D action spectrum. We suggest that by using this spectrum, and accounting for other factors that affect Vitamin D UV levels, a "Vitamin D Index" could be created. This could give more appropriate UV exposure advice than the current erythemal UV index alone, and reduce the worldwide burden of Vitamin D deficiency.

Introduction

Ultraviolet radiation (UVR) is responsible for the majority of both positive and adverse health effects associated with human sun exposure, with UVB (280 – 320 nm) causing the most acute biological response.

Humans obtain at least 90% of their dietary requirements of Vitamin D by exposure to solar UV, leading to synthesis in the skin (Holick, 2003). The main role of Vitamin D is to maintain calcium homeostasis by increasing the intestinal absorption of calcium. Vitamin D deficiency is a worldwide issue and its links to osteoporosis and rickets are well documented. Increased risk of other non-calcemic conditions include multiple sclerosis, hypertension, breast cancer, prostate cancer, colorectal cancer, insulin dependent diabetes and schizophrenia (Grant, 2006; Holick, 2003).

Recent research has shown that even adults living in South East Queensland (Australia) have surprisingly high rates of Vitamin D deficiency (8%) and insufficiency (23%) (McGrath *et al*, 2001). At the same time, this region has the world's highest incidence of skin cancer. This exemplifies the Vitamin D controversy, calling for a greater understanding of Vitamin D synthesis and effective public education regarding optimal UV exposure.

Objective

This project aims to contrast how the availability of Vitamin D UV and Erythemal UV vary over one year through computer simulation, and to suggest the need for a "Vitamin D UV" index (analogous to the current UV Index).

Background

The ability of the solar spectrum to induce a biological response is given by the relevant action spectrum. The action spectra for erythema (reddening of the skin after UV exposure) and Vitamin D synthesis (pre-Vitamin D formation after UV exposure) are noticeably different (figure 1). Vitamin D synthesis is confined to the UVB part of the UV spectrum, whereas the erythemal action spectrum extends into the UVA (320 to 400 nm) band.

Method

An established UV model (Green *et al* 1974, Schippnick *et al* 1982) was run by computer simulation at constant latitude (40ºS) over one year, and for different ozone concentrations from 260 to 340 DU (to understand to what extent ozone filtering affects Vitamin D availability). The outputted spectral UV data was weighted with the erythemal action spectrum (CIE, 1987) and the vitamin D action spectrum (Webb *et al*, 1988). Daily energy totals of both erythemal UV and Vitamin D UV were calculated.

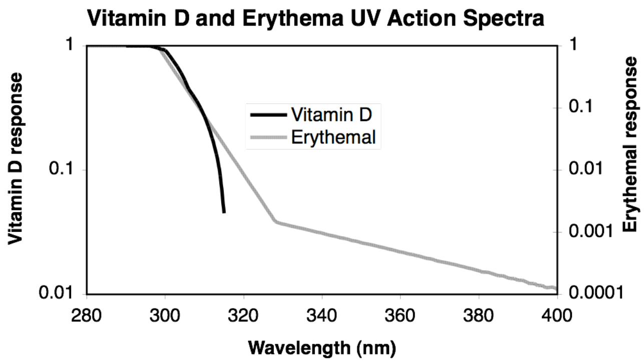

Figure 1. Action spectra for Erythemal UV (CIE, 1987) and Vitamin D UV (Webb *et al*., 1988; for conversion of 7-dehydrocholesterol to pre-Vitamin D).

Results

To compare the availability of Vitamin D UV to erythemal UV, the ratios of their daily energy totals were calculated and plotted for each day of the year. Secondly, the ratio from the 15th day of each month (to serve as an approximate average for that month) was plotted against the maximum solar zenith angle (SZA) on that day.

Analysis and discussion

From figure 1, the ratio of Vitamin D UV to erythemal UV in winter months is nearly a factor of two less in winter than it is in summer at 40ºS latitude. This is because at larger SZAs (during winter), greater attenuation of Vitamin D UV occurs than erythemal UV by ozone filtering. Therefore, the levels of Vitamin D UV reduce faster than the levels of erythemal UV with increasing SZA. Vitamin D production seems to be optimal during summer, whereas during winter, longer UV exposure seems necessary for maintaining Vitamin D sufficiency.

However, the final dose will obviously be determined in part by the area of skin exposed to the sun, not just the level of available Vitamin D UV. Not surprisingly, varying the ozone concentration in the model also affects the relative levels of vitamin D UV and erythemal UV – the ratio increases for decreasing ozone concentration, and this effect is also more sensitive in winter.

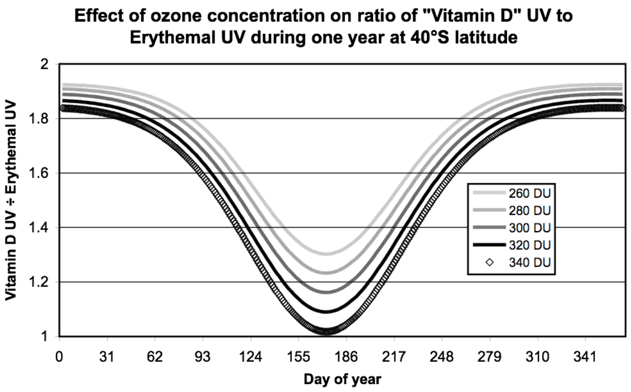

Figure 2. Ratio of daily totals of Vitamin D UV to Erythemal UV over 1 year.

Figure 3 plots the ratio from the 15th day of each month of the year against the solar noon SZA on that day. We note that, as discussed above, when the SZA (position of the sun and hence the path length of ozone filtering) changes, the ratio changes – i.e., the levels of Vitamin D UV and Erythemal UV are affected differently. This is because ozone filtering strongly affects the available Vitamin D UV levels since the vitamin D action spectrum is confined to the UVB band. In contrast, the erythemal response extends into the UVA region (figure 1), where ozone absorption is negligible. Hence, we conclude that the current UV index is not a complete measure of Vitamin D UV availability and hence it does not give complete advice regarding the beneficial effects of sun exposure.

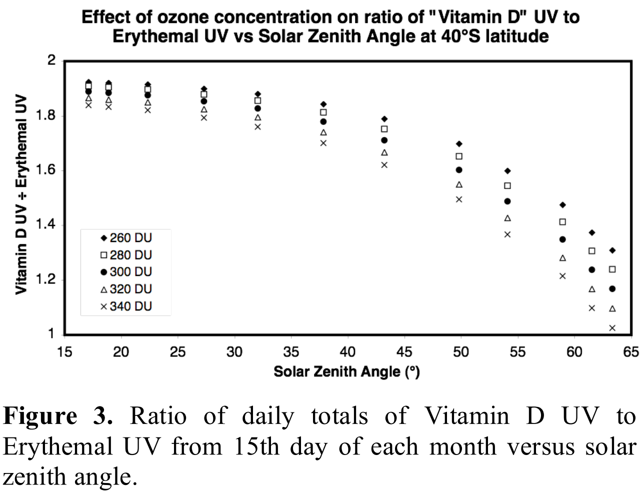

Figure 3. Ratio of daily totals of Vitamin D UV to Erythemal UV from 15th day of each month versus solar zenith angle.

Conclusion

From this research we suggest that the UV index (based solely on the erythemal action spectrum) is limited in its ability to provide advice on what might be considered appropriate UV exposure for vitamin D. This was demonstrated when the ozone levels and SZA varied, and Vitamin D UV levels were more strongly affected than erythemal UV levels. Indeed, other factors not investigated here including age, skin type and pollution would cause a different response in available Vitamin D UV compared to erythemal UV. We propose that the design and implementation of a "Vitamin D UV index" could reduce the worldwide burden of Vitamin D deficiency/ insufficiency by providing more balanced advice about UV exposure than the current erythemal UV index.

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