The duality nature of ultraviolet radiation exposure

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Abstract. Exposure to solar UV radiation has been considered for many years as a significant environmental carcinogen and all exposures should be avoided. Interestingly, human exposure to sunlight also has a nutritional impact, namely the development of pre-Vitamin D, which is an important nutrient in bone health. New research suggest that low vitamin D status may be a causative factor in the development of selective types of cancer and autoimmune diseases, as well as a contributing factor in bone health.

Introduction

Cancers of the skin are the most commonly occurring malignancies in fair-skinned populations around the world, associated with substantial costs for their diagnosis and treatment (Housman et al 2003). Recent estimates indicate that more than 800,000 new cases of squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) and more than 45,000 new cases of melanoma are diagnosed in the US population each year (Parker et al 1996). Some of the highest rates for cancers of the skin are observed among the Australian population, where more than 420,000 histologically-confirmed skin cancers are excised each year from within a population of 20 million, with cumulative risk to age 70 years of having at least NMSC were 70% for men and 58% for women (Staples et al 2006).

There is general agreement from epidemiological and molecular studies that exposure to ultraviolet (UV) radiation is the principal environmental cause of each of the common types of skin cancer (BCC, SCC, melanoma). Skin cancers tend to develop more frequently in fair skinned people with lightly pigmented eye and hair colour, tend to occur on parts of the body that are more often exposed to solar UV, are more likely to occur in sunny climates at low latitudes (Diffey et al 1996), and can be related to past personal histories of exposure to terrestrial UV.

Most people primarily depend on sun exposure to obtain vitamin D. When sunlight interacts with exposed skin, UVB photons (280 nm to 315 nm) are absorbed by 7-dehydrocholesterol in the skin, leading to its transformation to pre-vitamin D_3, which is rapidly (within two hours) converted to vitamin D_3. Vitamin D is unique in terms of its metabolism, physiologic features, and the human reliance on sunlight as well as exogenous sources (such as diet and fortified foods) to meet biological requirements.

The skin pigment melanin varies considerably in content and composition with both ethnicity and chronic sun exposure. Melanin can be thought of as providing the body with an effective “built-in” natural sunscreen. In dark-skinned races, an increase in melanin pigmentation reduces the efficiency of the sun-mediated photosynthesis of pre-vitamin D_3 due to the absorption of UVB radiation (Webb et al 1998). A combination of dark skin, living in high latitudes, and low dietary intakes of vitamin D leads to low circulating concentrations of 25(OH)D.

Vitamin D is known to improve bone mineral accrual by stimulating the synthesis of calcium-binding protein, enhancing calcium absorption in the gastrointestinal tract and increasing the amount of calcium available for incorporation into bone. Muscle cells contain the vitamin D receptors and several studies in the elderly have demonstrated that serum 25(OH)D is related to muscular performance. Because muscle or fat-free soft tissue (FFST) is the most important predictor of bone mass in children, there has been increased attention surrounding vitamin D and its potential to impact bone quality indirectly through metabolic roles in muscle.

UV Exposure

Season, latitude, time of day, skin pigmentation, aging, sunscreen use, and shade use all influence the UV exposure of humans. The season, time of day, and location have a significant impact not only on the *amount* of UV radiation available, but they also change the ratio between UVB and UVA. At high latitudes in winter little to no UVB is present on the earth’s surface, because the increased optical pathlength increases the amount of UVB absorbed by the atmosphere. This reduction and removal of UVB decreases skin synthesis of vitamin D because the wavelengths responsible for vitamin D formation lie clearly in the UVB part of the UV spectrum.

Vitamin D deficiency is common in older people, especially those who are homebound or living in institutionalized settings. Even in sunny Australia, recent studies of older people living in hostels or nursing homes in Victoria, New South Wales, and Western Australia, revealed that 80% of women and 70% of men were deficient in vitamin D, and 97% had levels below the median value of the healthy reference range (Flicker et al 2005, Sambrook et al 2002). These studies in a high UV environment gave an intriguing insight into vitamin D and older people. Clearly living in a high UV environment is not enough to ensure adequate vitamin D status.

Action Spectra

Various studies of animals and humans have determined the threshold of intensities of biological responses as a function of wavelength. Therefore, the ability of UV radiation to cause a biological response is wavelength dependent. The relative spectral efficiency in producing a biological response plotted as a function of wavelength gives the biological action spectrum for the response.

The effective irradiance, E_{eff}, is given by the following equation:

$$E_{eff} = \int_{\lambda} S(\lambda)\, A(\lambda)\, d\lambda \qquad (1)$$

Where $S(\lambda)$ – spectral irradiance at wavelength, λ
$A(\lambda)$ – the action spectrum for a given effect.

No biologically validated action spectra exist for Vitamin D formation, so a proxy method using photo conversion rates of Pro to Pre Vitamin D has been used (Webb et al, 1998). A word of caution on the use of action spectra. Although the biological action spectra can help in understanding of the interaction of radiation with tissue specific biological effects for specific wavelengths, they do not contain information on the simultaneous effect of polychromatic radiation exposures and feedback mechanisms that may also exist. Such exposures may dramatically change the biological response of the system being investigated.

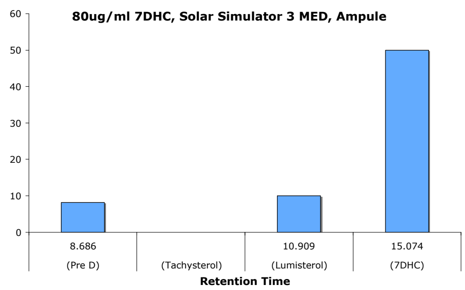
Many studies have used an *in vitro* model of vitamin D photoproduction for the assessment of the capability of sunlight to synthesize Vitamin D. In this work, we investigate this methodology and it's impact on Vitamin D synthesis.

Methodology

Using an in vitro model of vitamin D synthesis, 7-dehydrocholesterol at varying concentrations (20 to 100ug/ml) in ethanol solution was subjected to different levels of UV exposure under simulated UV radiation in a variety of receptacles that have been used previously for Vitamin D and UV synthesis experiments.

Results

After exposure to 3 MED of UV exposure over 5 minutes, and maintenance of temperature post exposure of 37^{o}C for 24hours, HPLC analysis of the photoproducts produced using various receptacles was performed.



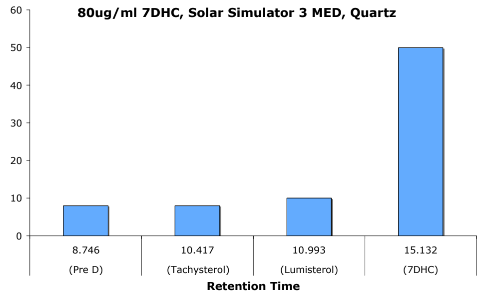


Figure 2. 7DHC UV irradiation photoproduct production.

Conclusions

The data presented in this work indicates that significant variations in determining the Vitamin D forming capabilities using an *in vitro* model dependant on the type of receptacle used. The receptacle materials tested were constructed of quartz, Pyrex and an ampule. Most studies using an *in vitro* model for Vitamin D synthesis use the ampule receptacle. Out results show that not all photoproducts are produced using the ampule when compared to the quartz container.

To understand why these results were obtained, we analyzed the spectral transmission of the solar simulated UV radiation through the various receptacles using a UV spectroradiometer with a solar simulated UV source. From this data, it is shown that the UV transmission spectra of the various receptacles differs, altering the amount and type of UV radiation entering. Researchers should be aware of this difference and it is suggested that the quartz receptacles are used, rather than the currently promoted ampules. Data suggest that a revision of the previous experiments for Vitamin D synthesis should be conducted to ensure accuracy.

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