SOLAR UVB RADIATION AND VITAMIN D SYNTHESIS: DIRECT MONITORING OF THE VITAMIN D SYNTHETIC CAPACITY OF SUNLIGHT IN KIEV AND IN ANTARCTIC

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1 INTRODUCTION

Small changes in solar UV-B radiation (280-315 nm) at the Earth's surface caused by ozone depletion may have a significant impact on biological systems. Excessive UV exposures are commonly associated with adverse health effects (erythema, skin cancer), but proper amounts of UV are beneficial for people and essential in the natural production of vitamin D_3 in skin that plays an essential role in calcium homeostasis [1].

Emerging new research indicates that vitamin D is a critical hormone that is more important to human health than previously thought. These investigations put a greater importance on vitamin D which the body develops from sunlight exposure. Recent epidemiologic studies [2] demonstrate that cancer mortality rates are correlated inversely with local solar UV-B doses for 13 types of cancer, and the most likely mechanism whereby solar UV-B radiation provides protection against cancer is natural production of Vitamin D.

The UV-B portion of sunlight converts provitamin D_3 (7-dehydrocholesterol, 7-DHC) in skin into previtamin D_3. Once formed, previtamin D_3 is thermally converted into vitamin D_3 (Figure 1). Just the photochemical stage vitamin D synthesis *in vitro* (ethanol solution of 7-DHC) was used for the first time [3] for direct measurement of the vitamin D synthetic capacity of sunlight. At that time HPLC-assisted analysis was applied to multicomponent photoisomer mixture formed during an exposure to sunlight due to the side photoconversions of previtamin D. Later on the original spectrophotometric analysis had been designed for an *in situ* 'antirachitic' UV dosimetry [4,5].

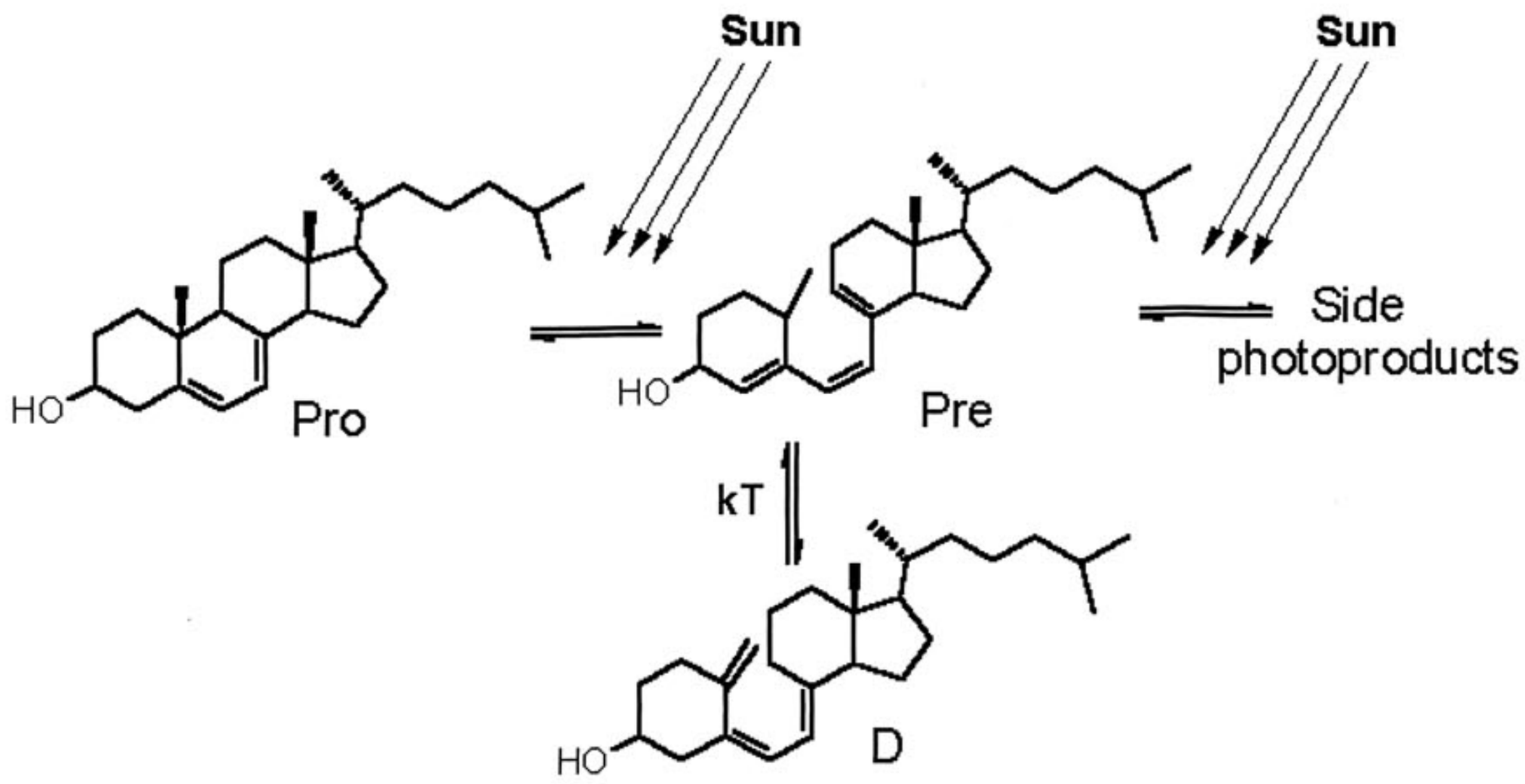

Figure 1. Schematic representation of vitamin D synthesis under solar irradiation

It is important to keep in mind that commonly used broadband radiometers that have an output in sunburn units, can not provide accurate data on the vitamin D synthetic capacity of sunlight because of significant difference between the CIE erythema and Vitamin D synthesis action spectra [4].

2 METHODS

Permanent monitoring of biologically active (antirachitic) solar UV radiation in Kiev ($50^0$23'N, $30^0$32'E) and at the Vernadsky station in Antarctic ($65^0$15'S, $64^0$16'W) was carried out during 2004. In Kiev two rectangular quartz cuvettes of 0.5cm thickness with 7-DHC ethanol solution (C = 20 mkg/ml) were exposed at the roof of the Institute of Physics building during 3 hours (from 11:30a.m. to 2:30p.m. local time). Normal incidence of sun rays to the cuvette plane was secured by specially developed servomechanism for auto tracking solar zenith angle. Additionally, in Antarctic the solution was exposed in spherical quartz cuvette to examine the albedo effect under global UV irradiance (Fig. 2).

Figure 2. Dr. Igor Gvozdovskyy installs quartz cuvettes with solution of 7-dehydrocholesterol for exposure to sunlight in Antarctic (left) and Ms. Tatiana Orlova provides UV monitoring in Kiev (right).

The solution absorption spectra were recorded before and after an exposure with UV-VIS spectrophotometer PerkinElmer Lambda 25 within spectral range 230-330 nm with a 1 nm step and further were processed with computer for concentration analysis [5].
In addition, accumulation of previtamin D accumulation during the exposures was calculated using the UV solar spectra calculated according to standard RT model [6] at the photoreaction model input [4].

3 RESULTS

The UV solar spectra were calculated for different ozone layer thickness. As an example, the calculated solar UV spectra for the minimum SZA = $41^0$48' (December 22, 12:00 local time, 16:00 GMT) at the Antarctic Vernadsky station and for the minimum SZA = $26^0$48' in Kiev (June 22, 13:00 local time, 10:00 GMT) are shown in Fig.3 together with provitamin D absorption spectrum.

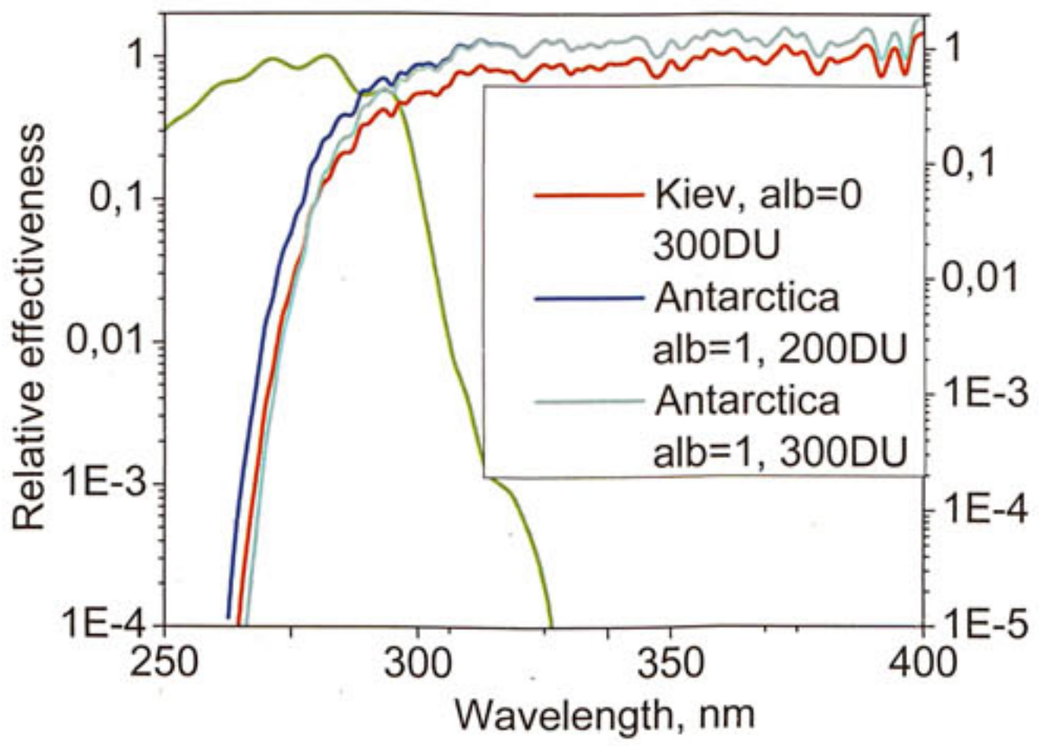

Figure 3. Calculated Solar spectra in Kiev and Antarctic using the Fastrt program (www.zardoz.nilu.no/~olaeng/fastrt/fastrt.html). Green line – the absorption spectrum of provitamin D.

Comparison of the experimentally measured and calculated (cloudless sky) concentrations of previtamin D in Kiev is shown in Figure 5 (left). The same data for the accumulation of previtamin D in Antarctic for global sunlight irradiation are shown in Fig. 5 (right) together with calculated concentrations of previtamin D.

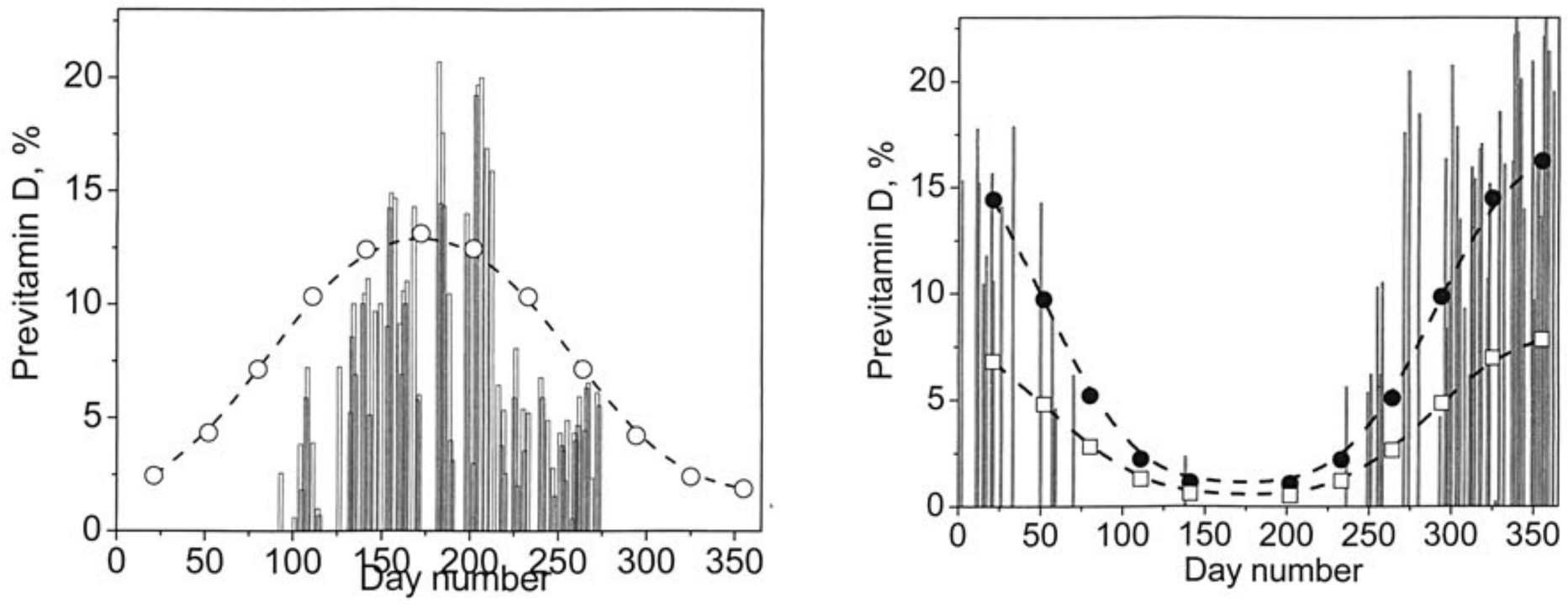

Figure 5. Experimentally measured photosynthesis of previtamin D (*in vitro*) in 2004 as a result of 3 hour exposure in Kiev (left) and in Antarctic (right) - *columns* and calculated concentrations for the ozone layer thickness 200 DU (*solid symbols*) and 300 DU (*open symbols*).

4 CONCLUSION

For the first time permanent monitoring of the vitamin D synthetic capacity of sunlight was carried out in Kiev and in Antarctic. The periods of the 'vitamin D winter' when vitamin D synthesis is inhibited due to the low levels of UV-B irradiance at the Earth's surface were determined both by calculations and experimentally. As one can see from Fig.5, during the observation period season and weather impact on solar UV radiation significantly affected the vitamin D synthetic capacity of sunlight. The role of stratospheric ozone layer thickness and of high albedo on the vitamin D synthesis in Antarctic is also clearly seen from Figure 5.

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REFERENCES

1. Holick, M., 1992: Vitamin D3 and sunlight: an intimate beneficial relationship, in: M.F. Holick, A.M. Kligman *(*Eds.*)*, Biological Effects of Light, W. de Gruyter, Berlin, 1992, pp. 11–33.
2. Grant, W., 2002: An estimate of premature cancer mortality in the US due to inadequate doses of solar ultraviolet-B radiation. Cancer 94: 1867-1875.
3. Webb, A., Kline, L., Holick, M., 1988: Influence of season and latitude on the cutaneous synthesis of vitamin D3: exposure to winter sunlight in Boston and Edmonton will not promote vitamin D3 in human skin, J. Clin. Endocrinol. Metabol. 67: 373–378.
4. Galkin, O, Terenetskaya, I. 1999: 'Vitamin D' biodosimeter: basic characteristics and prospect applications, J. Photochem. Photobiol. B: Biology, 53*:* 12-19
5. Terenetskaya, I., 2000: Spectral Monitoring of Biologically Active Solar UVB Radiation Using an *In Vitro* Model of Vitamin D Synthesis, Talanta, 53*:* 195-203
6. Bird, R., Riodtran, C., 1986: Simple solar spectral model for direct and diffuse irradiance on horizontal and titled planes at the Earth's surface for cloudless atmosphere, J. Climate Appl. Meteorol., 25*:* 87-97.