

## UV exposure, vitamin D and their relationship in a group of high school students at Davos

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**Abstract.** The relationship between UV exposure and vitamin D status was investigated with 7 high school students from Davos, Switzerland. The personal UV exposure was recorded using electronic dosimeters from March to August 2013, while blood samples were taken at monthly intervals to determine their serum concentration of 25(OH)D<sub>3</sub>. Questionnaires provided information on clothing worn, sunscreen use and activity. During school days only 1.7% of the ambient UV dose was reached, while 85% of the cumulative UV dose resulted from weekends and holidays. The observed average 25(OH)D<sub>3</sub> concentration increase was  $0.36 \pm 0.24$  ng/ml per 100 J/m<sup>2</sup> of vitamin D weighted UV exposure ( $r=0.88$ ).

### Introduction

It is well known that the body's primary source of vitamin D results from cutaneous exposure to sunlight.

Vitamin D regulates calcium and phosphorus metabolism and its essential role in bone health has long been recognized. In addition, there is now evidence that vitamin D may benefit a variety of other important functions, e.g. in modulating immune functions or reducing the risk of several cancers. On the other hand, vitamin D deficiency is associated with rickets in children; latest epidemiologic studies have linked insufficient vitamin D levels with an increasing risk of cancers, type I diabetes, autoimmune diseases and infections. Although just a relatively small amount of UV irradiation is capable of maintaining sufficient vitamin D, insufficient and deficient vitamin D status has been observed worldwide.

The quantitative relationship between the cutaneous synthesis of vitamin D and UV exposure is difficult to define due to genetical, geographical and behavioral differences among individuals. Yet all studies investigating this correlation were performed in urban environments; so far, no comparable research has been done in an alpine climate where the solar irradiance differs significantly from metropolitan sites. To seek clarification, a 6 month study among high school students was conducted at Davos (Switzerland), situated 1560 meter above sea level. The main objectives were to monitor the students' personal UV exposure and, consequently, to determine the relationship between their UV exposure and vitamin D status.

### Methods

**Study design.** From March to August 2013, 7 same-aged (17-18 years), male students from the Schweizerische Alpine Mittelschule Davos recorded their personal UV exposure using electronic dosimeters and had blood samples taken at monthly intervals to determine their 25(OH)D<sub>3</sub> concentration.

**UV dosimetry.** Personal UV exposure was measured by using state-of-the-art electronic UV dosimeters (Sherman, 2010). Throughout the study the dosimeters sampled UV

irradiance from 7 am to 10 pm in 5-second intervals. With these settings the daily number of gathered UV data points per participant exceeded 10,000, i.e. the whole study consists of over 10 million UV data points. Previous studies have shown that the wrist is a representative side for UV body monitoring (Knuschke et al. 2007). On these grounds participants wore their dosimeters like wristwatches on their wrist anytime they were outside.

Several problems led to data gaps which, as complete data series of all participants were required, had to be diagnosed and subsequently filled. Missing data was reconstructed based on the average UV exposure from the group of students during school time, resp. holidays. The measurement series of 2 participants consisted of more than 60% unreliable data due to failure of the dosimeters, and in view of the high reconstruction uncertainty, those time series were not analyzed any further. In the remaining 5 data series, approximately 20% of all data points had to be reconstructed.

The absolute calibration of the dosimeters was performed at PMOD/WRC during clear-sky days, several times throughout the study. Prior to the first absolute calibration all dosimeters passed through an aging process in order to minimize temporal variations. Absolute calibrations were performed through the comparison with an erythemally weighted broadband radiometer, which was directly calibrated against the travelling reference spectroradiometer QASUME (traceable to primary irradiance standard of PTB, Germany). To assure high data quality, the dosimeters were calibrated approximately every 6 weeks. A transfer model based on the CIE action spectrum for vitamin D allowed the conversion from the erythemally weighted UV values into UV irradiance relevant to the production of previtamin D. In addition to that, the personal vitamin D weighted UV exposure was corrected for exposed body area and sunscreen use.

**Vitamin D.** 7 blood samples were taken at monthly intervals starting at the beginning of March. The blood samples taken at the Hochgebirgsklinik of Davos were assayed at Labormedizinisches Institut Dr Risch (LI) using UHPLC and vitamin D status was reported in terms of the serum concentration of 25(OH)D<sub>3</sub> (CV 10%).

**Questionnaire.** Daily questionnaires provided information on clothing worn, sunscreen use, outdoor activity and fish consumption. The skin area exposed to UV radiation was estimated using the 'Rules of nine' (Wallace, 1951).

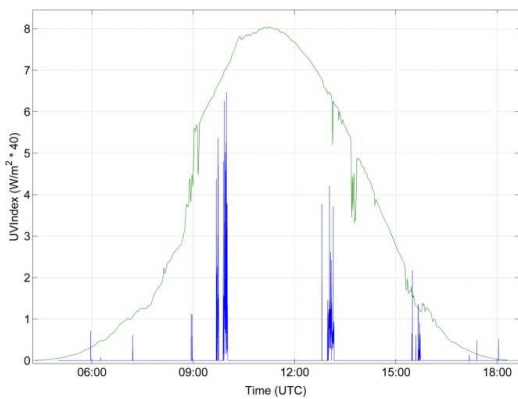
### Results

**Erythema UV exposure.** During schooldays the students gathered just a small fraction of the available ambient UV radiation. As in buildings UV radiation is

absorbed, they were only exposed to radiation on their way to and from school (see Figure 1). On average the school UV exposure represented only  $1.7 \pm 2.4$  % of the ambient UV dose. As expected, this fraction slightly increased towards summer and higher ambient temperatures.

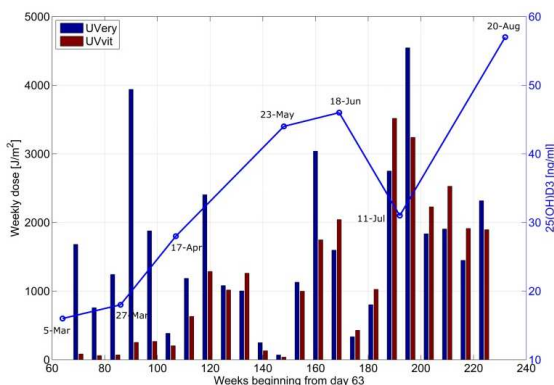
On the other hand, more than 85% of the cumulative UV exposure was acquired outside normal school days. Especially during holidays, the personal UV exposure increased significantly. During e.g. skiing more than 65% of the ambient UV dose was gathered.

Depending on the student's activity the total UV dose over the study period varied between 100 and 380 SED.



**Figure 1.** An example of a typical UV exposure during a school day (blue line) on the 23<sup>th</sup> of April 2013. The daily personal UV exposure is  $50 \text{ J/m}^2$ , which represents 1.25% of the ambient UV dose (green line).

**Vitamin D.** Throughout the study the average vitamin D insufficiency from the beginning of March (11.6 ng/ml 25(OH)D3) increased to a sufficient vitamin D supply with 42.4 ng/ml 25(OH)D3 in mid-August. The largest increase in vitamin D resulted in the spring and summer holidays, where the status increased by 53% on average. For half of the students, vitamin D levels declined again by an average of 25% between spring and summer due to reduced UV exposure during school.

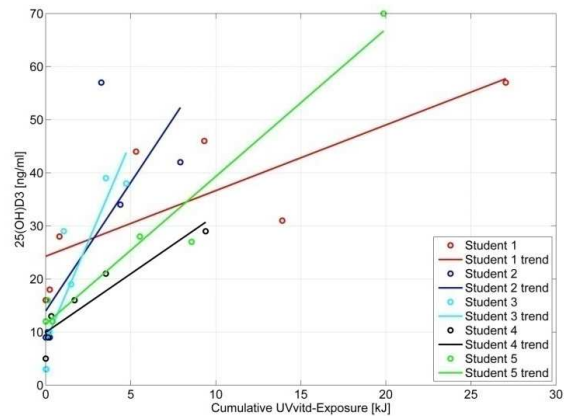


**Figure 2.** Summary of one student's weekly averaged UV exposure (erythemally weighted in blue and vitamin D weighted in red) for the study period. The blue line represents the 25(OH)D3 concentration. Note that the vitamin D weighted UV exposure was corrected for exposed skin area and sunscreen factor.

### Relationship between UV exposure and vitamin D.

Especially in wintertime huge differences between the erythemally,- and vitamin D weighted UV exposure were observed (see Figure 2). This was mainly due to the cold temperatures and the resulting minimal skin exposure to solar radiation. No significant differences in correlation between the erythemally weighted UV exposure ( $r=0.89$ ) and the vitamin D weighted UV exposure ( $r=0.88$ ) in terms of the increase in vitamin D levels were detected.

The effectiveness of the vitamin D synthesis through UV exposure varied among the students (see Figure 3). The average 25(OH)D3 concentration increased  $0.36 \pm 0.24$  ng/ml per  $100 \text{ J/m}^2$  vitamin D weighted UV exposure.



**Figure 3.** 25(OH)D3 concentration versus personal vitamin D weighted UV exposure for 5 students.

### Conclusion

The UV exposure and vitamin D status in a group of seven high school students at Davos, Switzerland (1560 m.a.s.l.) was monitored from March to August 2013. During the study period, the vitamin D status increased significantly, from initially insufficient concentrations to more than 40 ng/ml 25(OH)D3, reaching a sufficient level. Even in an alpine environment the decline in vitamin D status during winter months seems inevitable due to both geographical circumstances and little skin exposure to solar radiation. The average observed 25(OH)D3 concentration increase was  $3.6 \pm 2.4$  ng per litre per  $1 \text{ J/m}^2$  of vitamin D weighted UV exposure.

As the sample size and study period of this study were limited, a follow-up investigation with a larger group of participants over a longer period is suggested.

### References

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