Effects of measured UV exposure on Vitamin D status of New Zealanders: Implications for seasonal exposures required

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Abstract. We use results from an earlier study using personal UV dosimeters, to calculate for exposures required to maintain vitamin D levels among New Zealanders. We find that vitamin D levels can be maintained from equivalent full body exposures of approximately 0.4 SED per week, which is about double the exposure typically received outside the summer maximum period. If hands face and neck are exposed (10% of skin surface area), this corresponds to a range of noon exposure times required in New Zealand cities from about 3 minutes per day in the Auckland summer, to about 60 minutes per day in the Invercargill winter. These exposure times are well below those required for erythema.

Introduction

Approximately 200 volunteers from Auckland and from Dunedin took part in a trial where personal dosimeters were worn on the wrist over a 10 week period during daylight hours to record their full history of UV exposure. Diaries were also kept of clothing to enable calculation of skin coverage. From these data, the equivalent full body UV exposure (SED_{EFB}) was obtained, where 1 SED = 100 Jm^{-2} of erythemally-weighted UV. In the New Zealand summer, 1 SED is available in approximately 5 minutes at noon.

Blood assays were taken at weeks 4, 8, and 10 to assess the vitamin D status in terms of the blood serum concentrations of 25(OH)D. After approximately 9 weeks the participants received a (usually) single full body exposure of approximately 2 SED from one of four solaria, each with distinctly different spectral UV outputs. The main of the study was to determine which of four candidate action spectra for the first step in conversion of 7-dhydrocholesterol in the skin to vitamin D best matched the measured responses in 25(OH)D. Further details of the study have been described previously(McKenzie et al. 2013).

Results

The main results from that study (McKenzie et al. 2013; Scragg et al, 2014 subm.) can be summarised as follows:

- Personal equivalent full body UV doses were less than 1% of ambient levels.
- Mean levels of 25(OH)D were 45 ± 7 nmol/litre, showing that more than 50% of participants probably had below-optimal levels.
- Ambient exposures were insufficient to maintain levels of 25(OH)D over the predominantly winter period.
- Exposures from the solaria reversed the seasonal decline in 25(OH)D
- The action spectrum for erythema is as good as any of the proposed action spectra for vitamin D for describing the observed response from the 4 solaria.
- There is a large variability between individuals in their UV exposures, their baseline 25(OH)D levels, and their vitamin D response to UV.
- The mean response was 1.8 nmol/litre per SED_{EFB}.
- There was no significant difference in response for different skin reflectance, BMI, gender, or age.
- The only significant difference was for race, with Asians and Europeans having a slightly lower response (~1.5 nmol/litre per SED_{EFB}) than Maori or Pacific Islanders (~2.2 nmol/litre per SED_{EFB}).

Discussion

In Figure 1 we show the mean and median changes in 25(OH)D as a function of the UV exposure per week for the first period of ambient UV exposures, and for the second period that includes the sunbed exposure. Median exposures are lower than means because the distribution of exposures was skewed, with a small number of participants receiving much higher UV doses than the mean.

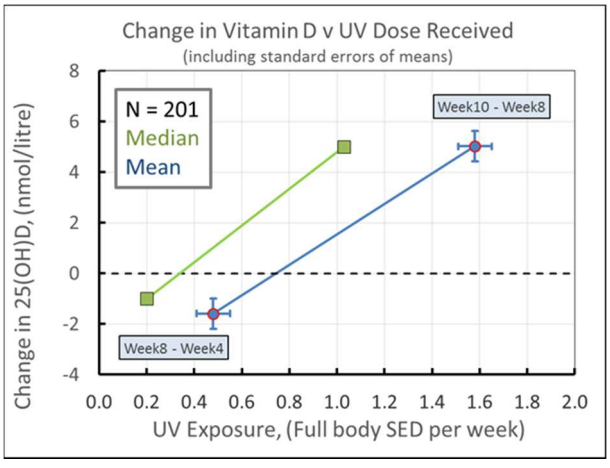

Figure 1. Changes in 25(OH)D from ambient UV exposure during weeks 4 to 8, and from the exposure that included the sunbed exposure during weeks 8 to 10.

For both periods, the daily UV doses were small (< 0.2 SED/day), so expected changes in 25(OH)D are approximately linear in UV dose. Thus the changes in 25(OH)D for intermediate UV doses may be approximated

by the straight lines joining the two data points. Thus we see that the median and mean doses needed to maintain these average levels of 25(OH)D are 0.3 and 0.7 SED_{EFB} per week respectively, or about twice the ambient dose that was received. Thus to maintain current levels of vitamin D in this population, the exposure needed would be about twice what they actually received.

This study was a subset of a larger study in which changes in vitamin D were measured for a larger number of participant (approximately 500) between week 4 and 8 using only ambient exposures. That study found a similar value of 0.4 SED_{EFB} required to maintain vitamin D status (Scragg et al. 2014, submitted), which is intermediate between the mean and mean values deduced here.

Based on an assumed requirement of 0.4 SED_{EFB} per week, we can then estimate the weekly exposure time of noontime that should be required to maintain a serum 25(OH)D level of 45 nmol/litre as a function of location and season. The calculations presented in Table 1, assume monthly mean climatological UVI values that have been calculated previously for sites in New Zealand (McKenzie, 2008). The deduced exposure times in this table are in reasonable agreement with those published previously, which were based on more theoretical calculations (McKenzie, et al. 2009). However, the tabulated times are based on the CIE erythemal action spectrum rather than the CIE action spectrum for vitamin D. Consequently, the times required in winter when the UVI is 1 or less are shorter than calculated previously.

Table 1. Calculated mean noon time exposure period in minutes per week needed to maintain vitamin D status in New Zealand, assuming hands, head and neck (10% skin cover) exposed. Shorter periods would be needed if larger skin areas are exposed.

	Mar	Jun	Sep	Dec
Auckland	26	116	38	19
Wellington	27	157	48	20
Christchurch	32	243	58	23
Central Otago	33	191	54	22
Invercargill	40	334	64	25

The required weekly noon exposure times shown in Table 1 are for clear skies. Under cloudy conditions, the times required could be more than twice as long, and for mean cloud conditions, the times are approximately 1.5 times longer. Exposure times are longer outside the noon period, and it would be impractical to receive sufficient UV from winter sunlight without some exposure near the noon period (i.e., between 12:00 and 13:00 NZST).

It is relatively easy to synthesize sufficient vitamin D in the summer. For example, in the Invercargill 25 minutes per week (or about 3 or 4 minutes per day) would be required if only 10% of the skin surface area is exposed. For full body exposure, less than 1 minute would be needed. Casual exposures to summertime UV can therefore provide enough UV for vitamin D sufficiency without danger of erythema.

Conclusions

We have shown that vitamin D levels can be maintained from weekly equivalent full body exposures of approximately 0.4 SED, which is about double the exposure typically received by New Zealanders outside the summer maximum period. If hands face and neck are exposed (10% of skin surface area), this corresponds to a range of noon exposure times required in New Zealand cities from about 20 minutes per week (i.e., ~3 minutes per day) in the Auckland summer, to over 330 minutes per week (i.e., ~60 minutes per day) in the Invercargill winter. These exposure times are well below those required for erythema.

The calculated exposure times are approximate only, with uncertainties of at least ±10%, and perhaps larger in winter if the action spectrum differs from the CIE erythemal action spectrum assumed here. Variability between people, and probable dependencies on their baseline levels of 25(OH)D are also expected. There is also disagreement on the optimal levels of 25(OH)D. If it is significantly higher than 50 nmol/litre as some have suggested, then the exposure times required to maintain optimal levels would be much longer than calculated here. There are also limitations on the accuracy associated with using irradiances rather than actinic flux, as discussed elsewhere(Seckmeyer et al. 2013).

Finally it must be stated that, as for our previous studies, these results contradict the previously-held notion that no vitamin D is produced in the winter. They do however imply that its production in winter is slow, and we suggest that studies of wintertime production may not have had sufficient sensitivity to detect the small changes. Clearly, it would be difficult to maintain of vitamin D from winter sunlight alone in Southern New Zealand.

References

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