Seasonal variation in vitamin D levels and UVB exposure in Christchurch

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Abstract. We measured plasma 25OHD and incident solar UVB radiation in Christchurch during 2004, and modelled the relationship between them. 25OHD (DiaSorin), total calcium (Ca_T) (Aeroset), ionised calcium (Ca_I) (Corning C865) and parathyroid hormone (PTH) (Elecsys) were measured in 201 healthy volunteers (median age 45 yrs, range 18 to 83) between February and July 2004. Vitamin D-weighted (Maclaughlin) UV energy measurements (dUV) for Christchurch were from the NIWA UV Atlas. In February, 88% of 25OHD levels were below 75 nmol/L, increasing to 100% in June and July. Severe deficiency (<12.5 nmol/L) was found in 1.5% of subjects. From February to July, 25OHD and Ca_I fell and Ca_T rose (all p <0.001). No correlation was found between 25OHD and PTH, but Ca_T and Ca_I correlated negatively with PTH (both $p < 0.001$). Monthly mean dUV intensity ranged from 10 $kJ \cdot m^{-2} \cdot day^{-1}$ in Dec 2003 to 0.5 $kJ \cdot m^{-2} \cdot day^{-1}$ in Jun 2004. Compartmental modelling estimated that a Christchurch person made 1200 IU/day of vitamin D in mid-summer but only 60 IU/day in midwinter. Daily supplements of 1800 or 2900 IU vitamin D_3 are predicted to raise the annual minimum average plasma 25OHD to 75 or 100 nmol/L respectively

Introduction

It has been proposed that the optimal plasma concentration of 25-hydroxyvitamin D_3 [25(OH)D] should be at least 75 nmol/L (Vieth 2007, Bischoff-Ferrari 2006,). This figure is based both on observational evidence relating 25(OH)D levels to the risks of fracture, periodontal disease, colorectal cancer and lower-extremity muscle weakness. Within New Zealand, a survey of the Auckland workforce found that a large proportion of the workers, if not the majority, had serum 25(OH)D concentrations below 75 nmol/L (Scragg 1995). In a survey of New Zealanders aged 15 years and older, 3% were considered to have frank deficiency (<18 nmol/L) and 48% insufficiency, based on a cut-off of 50 nmol/L (Rockell 2006), and with differences apparent due to age, gender, latitude and season. We now report the relationship between plasma 25(OH)D levels and solar UV in the general adult population in a southerly New Zealand location. We also model predictions of vitamin D metabolism to assist in the effective remediation of poor vitamin D status.

Methods

Volunteer subjects (n=201) were residents of Christchurch, New Zealand (44°S), recruited from electoral rolls or advertisement to a study to establish reference intervals for endocrine test methods. They completed a questionnaire and were accepted if aged 18 or over, considered themselves healthy and did not meet

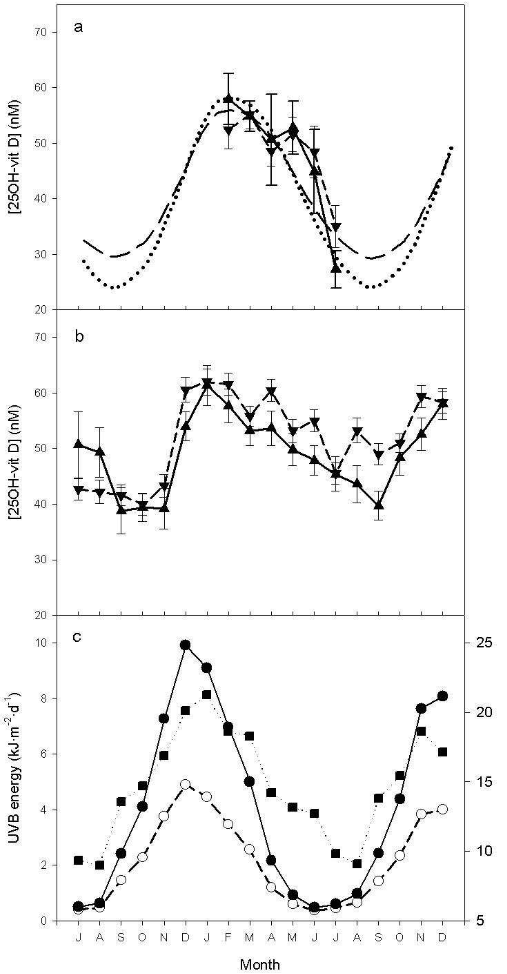

Figure 1. Monthly plasma 25-hydroxy vitamin D concentrations in male and female Christchurch residents (mean±sem) for (*a*) the volunteer group and (*b*) the patient group. ▲——▲ male, ▼——▼ female. The smooth dashed line in *a* is the prediction of the best-fit model (dietary vitamin D 350 IU/d), and the dotted line shows the best fit if dietary vitamin D is assumed to be 200IU/d. Panel *c* shows the corresponding monthly means of the UVB energy received daily at ground level and the maximum daily temperature. The first month is July 2003 and the last December 2004. ●——● dUV, ○ - - - ○ eUV, ■ · · · ■maximum temperature.

exclusion criteria that included diabetes and endocrine conditions, relevant cancers, steroid medication and recent hospitalisation. A single morning blood sample was collected within the period of Feb to Aug 2004 from 209 individuals of whom 105 were fasting. After excluding those who did not meet the above criteria or who were taking vitamin D supplements or cod-liver oil, 25(OH)D measurements were available for 201 volunteers. Mean (±sd) age was 46±14 years with a median of 45 years (range 18 to 83) and the mean (±sd) body mass index was 26.3±4.7.

The patient group came from within the Christchurch region from whom samples were submitted for measurement of plasma 25(OH)D between 1st July 2003 and 31st December 2004. It comprised 3702 samples from females and 1138 from males, with a mean (±sd) age of the whole group of 59±23 years and a median age of 63 years (range 0.1 to 101). Samples were submitted from hospital wards, outpatient clinics and private practices. It is not known how many patients were taking vitamin D supplements.

25(OH)D was measured using the DiaSorin radioimmunoassay kit (Stillwater, MN, USA). The low, medium and high QC values with coefficients of variation are 16.5 (16.2%), 35.9 (7.8%) and 132 (7.8%) nmol/L.

Plasma calcium was measured on the Abbott Aeroset analyser (Abbott Laboratories, Abbott park, IL, USA) by colorimetry using the Arsenazo-III dye method (intra-assay CV 0.8% at 3 mmol/L). Serum ionised calcium was measured on the Corning C865 blood gas analyser (Ciba Corning Diagnostic; Medfield, MA, USA) by calcium ion-selective electrode (between-batch CV 1% at 1.22 mmol/L). Parathyroid hormone (PTH) was measured using the Roche Elecsys 2010 system. The low, medium and high QC values with coefficients of variation are 2.2 (6.9%), 8.2 (5.3%) and 31.5 (4.7%) pmol/L for PTH and 0.46 (7.5%), 0.59 (10.4%).

Daily UV irradiances (W/m^2) at one hour intervals were taken from the NIWA UV Atlas software package (http://www.niwascience.co.nz/services/uvozone/atlas). The irradiances for Christchurch were summed to give the mean for each month of total erythemally-weighted UV (eUV) and vitamin D-weighted UV (dUV) per day.

Results

Plasma 25(OH)D tended to rise as UVB energy rose in spring and to fall as UVB energy fell in autumn (Figure). The 25(OH)D levels tended to lag behind UVB. The large majority had below optimal levels (< 75 nmol/L) regardless of the time of year and the majority showed insufficiency (< 50 nmol/L) in June, July and August. Frank deficiency (< 25 nmol/L) was evident in at least a few individuals in each month studied and rose to 35% of the volunteer group in July-August. Only 1.5% of the volunteers had 25(OH)D below 12.5nmol/L (one person in May and two in July). As the year progressed 25(OH)D levels fell ($p < 0.001$), total calcium rose ($p < 0.001$) and ionised calcium fell ($p < 0.01$, $p < 0.001$). PTH levels were neither significantly correlated with time of year nor with 25(OH)D levels. The quantity of supplemental vitamin D needed to raise the modelled annual minimum plasma 25(OH)D in the volunteer group to 75 nmol/L is predicted to be 1800 IU/d (45µg/d), or to raise it to 100 nmol/L, 2900 IU/d (73 µg/d). On the other hand, if year-round sunlight exposure were to be doubled, in the absence of supplementation, the annual maximum plasma 25(OH)D is predicted to rise from 56 nmol/L to 80 nmol/L and the annual minimum to rise from 29 nmol/L to 37 nmol/L.

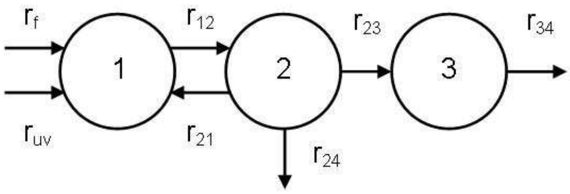

Figure 2. Model of vitamin D metabolism. Compartments 1 and 2 contain vitamin D_3 and compartment 3 contains 25(OH)D; 4 denotes further (undefined) metabolites. Rates (nmol/day) are denoted r and rate constants k. Parameters α and β define the feedback of 25(OH)D on its production rate. r_f = dietary vitamin D_3, $r_{uv} = k_{uv} E_{uv}$, E_{uv} = dUV energy, $r_{12} = k_{12}c_1$, $r_{21} = k_{21}c_2$, $r_{24} = k_{24}c_2$, $r_{23} = k_{23}c_2 = c_2\alpha/(1+\beta c_3)$, $r_{34} = k_{34}c_3$.

Discussion

The two principal findings of this study are firstly that most, if not virtually all, of the apparently healthy general population in Christchurch do have not adequate circulating levels of 25(OH)D at some time during the year, and secondly that relatively high levels of supplementation with vitamin D would be required to achieve healthy concentrations of 25(OH)D year round.

References

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