Seasonal Changes in UVB Availability in Europe and Associations with Population Serum 25-Hydroxyvitamin D

Low vitamin D status is common in Europe, with one in eight individuals (13%) reported to have vitamin D deficiency (i.e. serum 25-hydroxyvitamin D [25(OH)D] concentration <30 nmol/L) [1].

The major source of vitamin D in humans is ultraviolet B (UVB) radiation in sunshine. It has been estimated that vitamin D production in skin provides between 80-100% of the body's vitamin D requirements [2], and that food sources play a lesser role. Vitamin D is produced when UVB radiation reaches 7-dehydrocholestol in the skin, and there are a number of personal and environmental factors that can help or hinder this first step [3]. The personal factors include skin colour/pigmentation, age, clothing, use of suncreeen and sun exposure behaviour, while the environmental factors that determine if UVB radiation of sufficient strength is available for skin production of vitamin D include season, latitude and time of day.

One of the objectives of the ODIN project was to assess vitamin D effective UVB availability across several European locations ranging from 35°N to 69°N and to compare these UVB data with population serum 25(OH)D data from Ireland (51-54°N), Iceland (64°N) and Norway (69°N), as examplars.

This work was a collaboration between ODIN research partners in the UK, Ireland, Norway, Iceland and the USA under the direction of Professor Kevn Cashman of the *Centre for Vitamin D and Nutrition Reserach* at University College Cork, Ireland.

UVB availability was modelled for nine European countries/regions using a validated UV irradiance model [4] which used data collected daily over a 10 year period between 2003 and 2012. A threshold of 1000 Jm^{-2} was used as a guide to a UVB dose below which very little vitamin D is produced in skin. The number of months in a typical year (mean of 10 years) for which the modelled UVB dose was less than this 1000 Jm^{-2} was used as an estimate of the duration of "vitamin D winter" in each location. Standardized serum 25(OH)D concentrations were accessed from the ODIN project [1].

The study showed a clear trend of decreasing UVB availability on moving from South to North within Europe (see **Figure 1**) with an almost six-fold difference in average modelled UVB availability between the two latitude extremes, namely Crete in Greece and Tromsø in Norway. The data highlight very clearly the increasing length of "vitamin D winter" within Europe as one moves from 35°N (which has essentially no vitamin D winter) to 69°N, which has eight months of "vitamin D winter". Much of mid-Europe has a "vitamin D winter" of four to six months during which time very little, if any UVB of sufficient strength is available for vitamin D skin production. All of the locations showed a clear seasonal variation in UVB availability and it was striking that in December throughout all of Europe, none of the locations studied had UVB of sufficient strength for vitamin D skin production (**Figure 1B**).

The mean (and standard deviation) for the monthly 25(OH)D concentrations from health surveys in Ireland (51-54°N; see **Figure 2A**), Tromsø, Northern Norway (Latitute 69°N; see **Figure 2B**), and Rejkjavik, Iceland (64°N; see **Figure 2C**) were superimposed onto the graph of monthly mean modelled UVB doses. The data show that there was a clear seasonal variation in serum 25(OH)D concentration in Irish adults ($p<0.0001$) which peaked in late summer peak and was lowest in late winter, separated by 25nmol/L. The seasonal fluctuations in serum 25(OH)D concentrations broadly tracks, albeit with a slight lag, that of UVB availability for Ireland. While there was significant seasonal variation in serum 25(OH)D concentration in adults in Reykjavik and Tromsø, it was more blunted than that seen in Irish adults. The lowest winter serum 25(OH)D concentrations in both of

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration (Grant Agreement no. 613977)

these Northern European populatons (54.8 and 56.9 nmol/L, respectively) were much higher than for the Irish population (40.6 nmol/L), despite much reduced UVB availability in the former countries and "vitamin D winters" of seven and eight months for Reykjavik and Tromsø, respectively. The more favorable vitamin D status in Northern Europe compared with mid-Europe is most likely due to a combination of factors including important differences in dietary vitamin D intake but also possibly paler skin pigmentation of indigenous populaton at higher latitudes [5] and well as more conscious sun-seeking behaviour and sun holidays amongst Northern Europeans. In terms of intake differences, nutrition surveys in Iceland and Norway report much higher vitamin D intake (~12 µg/d) from foods and supplements compared with that in Ireland (~5 µg/d). The higher vitamin D intakes in Norway and Iceland are most likely due to higher intake of cod liver oil both in traditional foods and as supplements, and a higher intake of fatty fish.

Overall, modeled UVB dose data for European countries from this ODIN study highlight differences in vitamin D effective UVB availability which occur due to latitude and seasonality. It also highlights how increasing the vitamin D intake can ameliorate the impact of low UVB availability on serum 25(OH)D status in Europe.

Click on the following link to the paper describing the full study http://www.mdpi.com/2072-6643/8/9/533

References

1. Cashman KD, Dowling KG, Škrabáková Z, Gonzalez-Gross M, Valtueña J, De Henauw S, Moreno L, Damsgaard CT, Michaelsen KF, Mølgaard C, Jorde R, Grimes G, Moschonis G, Mavrogianni C, Manios Y, Thamm M, Mensink G, Rabenberg M, Busch MA, Cox L, Meadows S, Goldberg G, Prentice A, Dekker JM, Nijpels G, Pilz S, Swart KM, van Schoor NM, Lips P, Eiriksdottir G, Gudnason V, Cotch MF, Koskinen S, Lamberg-Allardt C, Durazo-Arvizu RA, Sempos CT, Kiely M Vitamin D deficiency in Europe – Pandemic? Am J Clin Nutr 2016;103(4):1033-44.

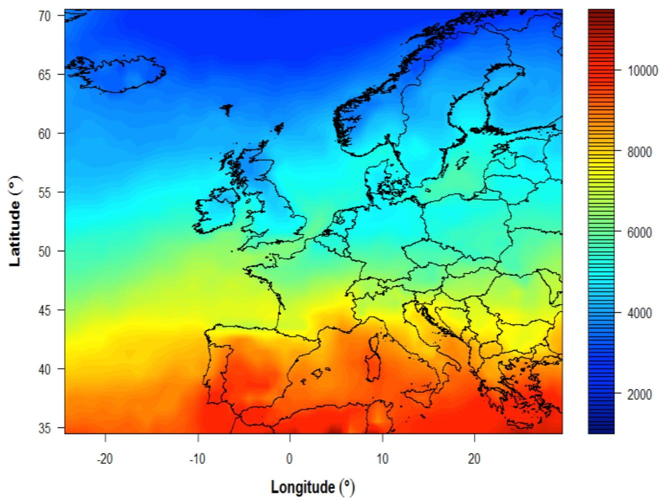
2. Kimlin MG. Geographic location and vitamin D synthesis. Mol Asp Med 2008; 29:453-461.

3. Webb AR. Who, what, where and when-influences on cutaneous vitamin D synthesis. Prog Biophys Mol Biol 2006; 92:17-25.

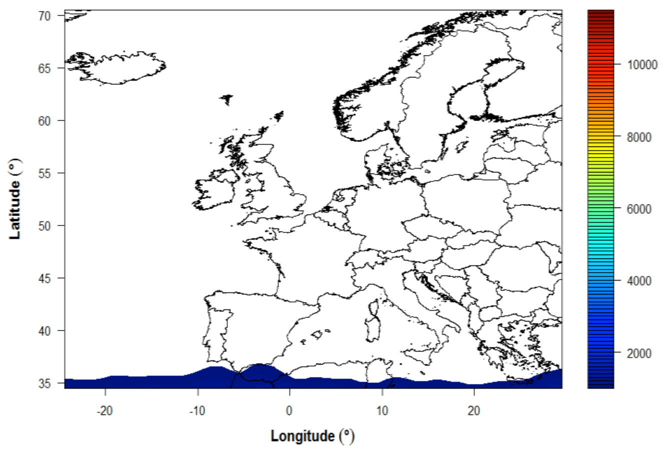
4. Kazantzidis A, Smedley A, Kift R, Rimmer J, Berry JL, Rhodes LE, Webb AR. A modelling approach to determine how much UV radiation is available across the UK and Ireland for health risk and benefit studies. Photchem Photobiol Sci 2015; 14:1073-1081.

5. Jablonski NG, Chaplin G. Human Skin pigmentation, migration and disease susceptibility. Philos Trans R Soc Lond B Bio Sci 2012; 367:785-792.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration (Grant Agreement no. 613977)



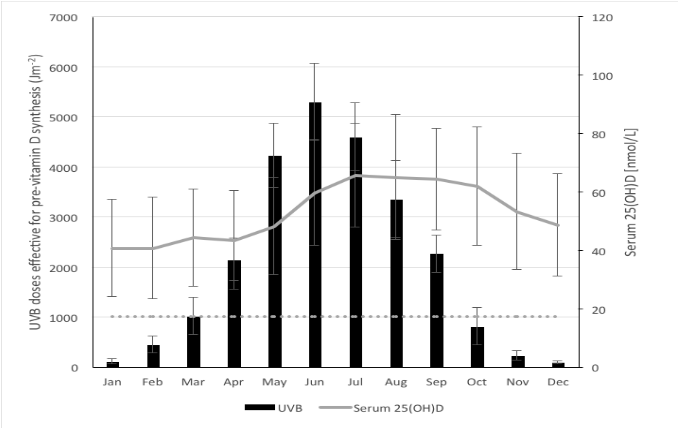
(**A**)



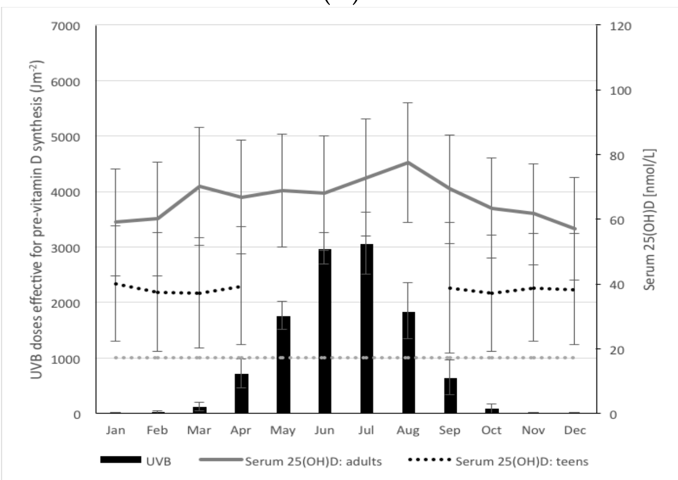
(**B**)

Figure 1. Mean monthly modeled UVB doses effective for pre-vitamin D_3 synthesis (Jm^{-2}) across Europe for June (**A**) and December (**B**), based on average of data from years 2003–2012. Scale begins 1000 Jm^{-2}.

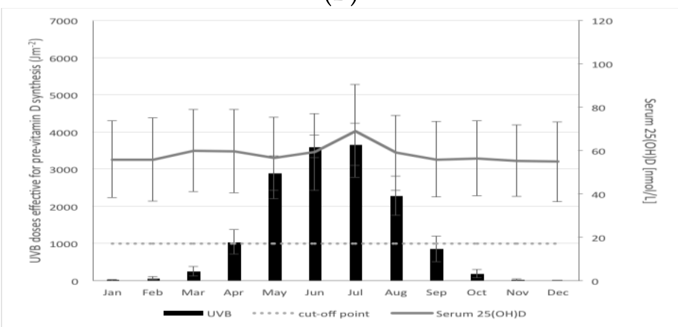
This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration (Grant Agreement no. 613977)



(**A**)



(**B**)



(**C**)

Figure 2. Mean modeled UVB doses effective for pre-vitamin D_3 synthesis (Jm^{-y}) on a monthly basis in a typical year (mean of 2003–2012) in Ireland (51–54° N) and mean (SD) monthly serum 25(OH)D measured in adults (18–84 years) in the National Adult Nutrition Survey in Ireland [21] (**A**); in Tromsø, Northern Norway (69° N) and mean (SD) monthly serum 25(OH)D measured in adults (18–83 years) in the regionally representative Tromsø sixth cycle cohort [17] (solid line) and adolescents (15–18 years) in the Tromsø—Fit Futures study [18] (dotted black line) (**B**); and in Reykjavik, Iceland (64° N) and mean (SD) monthly serum 25(OH)D measured in adults (aged 66–96 years) in the regionally representative AGES-Reykjavik cohort in Iceland [19] (**C**). Note: Data on serum 25(OH)D for the four summer months (May to August) are absent in Tromsø—Fit Futures study as the adolescents were not sampled in this period due to school summer vacation. Dotted line reflects a threshold of 1000 Jm^{-0} as a guide to a dose below which dermal synthesis of pre-vitamin D_3 is relatively low. Black bars and error bars represent mean and SD monthly UVB doses, respectively.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration (Grant Agreement no. 613977)