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Review

Quantifying the non-food sources of basal vitamin D input

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ABSTRACT

Unsupplemented vitamin D status is determined by cutaneous synthesis and food inputs; however, their relative magnitudes are largely unknown. In a cohort of 780 non-supplement-taking adults with a mean serum 25-hydroxyvitamin D [25(OH)D] of 33 (±14) ng/ml we assessed the relationship between serum 25(OH)D and non-food environmental variables. Serum 25(OH)D concentration was adjusted for seasonal influence (which removed 2% of the total variance) and these adjusted values were regressed against factors involved in cutaneous synthesis. Indoor tanning use, sun exposure, and percent of work performed outdoors were significantly positively associated and body mass index (BMI) was significantly negatively associated with 25(OH)D values ($P < 0.03$ for each). Latitude, gender, and age were not significantly correlated ($P > 0.10$). Season and non-food predictors together explained 13% of the total variance in serum 25(OH)D concentration. Non-traditional food sources need to be investigated as possible vitamin D inputs.

This article is part of a Special Issue entitled 'Vitamin D Workshop'.

Contents

1. Introduction

Vitamin D status in individuals not taking supplements is determined by cutaneous synthesis of vitamin D and food inputs. Heaney et al. demonstrated that non-supplemented adults have basal, all-source vitamin D inputs of approximately 2000 IU/day [1]. Traditionally estimated food sources typically account for <200 IU/day, which leaves either cutaneous synthesis or an unidentified source to account for the difference [2].

Factors influencing cutaneous synthesis, such as sun exposure, latitude and body size, have been shown to be associated with vitamin D status; however, the relative magnitudes are unknown [3–6]. Also, there is a recognized need to adjust serum level values for seasonal variation.

GrassrootsHealth (GRH), a nonprofit public health research organization running a large population based study, has assembled a database with serum 25-hydroxyvitamin D [25(OH)D] measurements and information on vitamin D supplementation, demographics, and UVB exposure. Our objective was to use GRH data to examine the relationship between serum 25(OH)D and non-food variables among non-supplement-taking participants aged 16 years and older.

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2. Materials and methods

2.1. Participants

Participants were individuals who responded to an invitation to attendees at a GRH seminar in 2008, and others recruited via internet invitations. Participation included submission of a home blood spot 25(OH)D test kit and completion of an online health questionnaire. This cohort has individuals residing in 45 countries worldwide. All participants have given informed consent, and this research study was approved by the Western Institutional Review Board (Olympia, WA), WIRB study 1126093.

2.2. Data collection

Between January 2009 and February 2012, participants reported their gender, age, use of indoor tanning, and percent of occupation performed outdoors. Body mass index (BMI) was calculated using self-reported weight and height, and latitude was determined by city of residence. Reported time spent outdoors was adjusted by type of clothing and sunscreen use to determine the average daily amount of time spent outdoors between 10 a.m. and 2 p.m. for sun-exposed skin. The outcomes of interest, serum 25(OH)D3 and total 25(OH)D, were determined by blood spot test kits analyzed using liquid chromatography–mass spectroscopy (LC–MS/MS) by ZRT Laboratory (Beaverton, OR). ZRT's assay has been validated against the LC–MS/MS consensus group reporting to the Vitamin D Quality Assessment Scheme (DEQAS), whose objective is to ensure the analytical reliability of 25(OH)D assays, with an R^2 value of 0.998. Both serum measurements were of interest because 25(OH)D3 is expected to be affected by environmental factors, whereas 25(OH)D2 [contained within total 25(OH)D] would not.

2.3. Statistical methods

Serum 25(OH)D3 values were adjusted for season using methods described in Heaney et al. [1]. Briefly, an adjustment formula was derived from plotting the values against day of the year using a sine wave model in SigmaPlot 12.3 (Systat Software Inc., San Jose, CA). Pearson's correlation was used to measure the association between season-adjusted 25(OH)D3 and 25(OH)D values and predictor variables. Stepwise multiple linear regression was used to determine which variables, with a correlation $P < 0.10$, were independently associated with adjusted 25(OH)D3 and 25(OH)D values. Statistical analyses were performed using SPSS statistics version 20 (IBM, Armonk, NY).

3. Results

There were 780 non-supplement-taking participants aged 16 years and older with a mean serum 25(OH)D of 33 (±14) ng/ml.

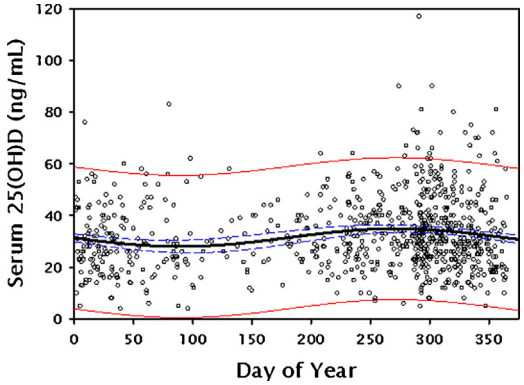

Fig. 1. Plot of measured 25(OH)D3 concentrations against day of blood spot test. January 1 is assigned a day value of zero. Day of year was shifted 183 days for participants in the southern hemisphere. The central curvilinear line is the least squares best fit of the data to a sine wave curve, the inner dashed lines reflect the 95% confidence limits and the outer dashed lines reflect the 95% probability range.
Source: Copyright Robert P. Heaney, 2012. Used with permission.

The gender distribution was 65% females and 35% males; mean age was 48 years (±13); mean weight was 74 kg (±18); mean BMI was 25 kg/m^2 (±5); and mean latitude (N or S) was 40° (±7).

The amplitude (a) of the seasonal oscillation was 3.43 ng/ml (Fig. 1). In correlation analyses, weight, BMI, percent of work performed outdoors, sun exposure, and use of indoor tanning were each significantly correlated ($P < 0.10$) with 25(OH)D3 and 25(OH)D, adjusted for season (Table 1). Latitude, sex, and age were not significantly correlated.

Variables significantly associated with adjusted 25(OH)D3 and 25(OH)D in stepwise multiple linear regression were indoor tanning use, sun exposure, BMI, and percent of work performed outdoors (Table 1). Serum levels increased about 1.2 ng/ml for every 30 min spent outdoors daily and decreased about 0.4 ng/ml for every one point increase in BMI.

Of the total variance in vitamin D status, about 9% was explained by UVB exposure, 2% by season, and 2% by BMI. The absolute standard deviation of unadjusted 25(OH)D was 13.6 ng/ml; it was 13.5 ng/ml after accounting for season, 13.3 ng/ml after BMI, and 12.7 ng/ml after UVB exposure.

4. Discussion

Of the non-food factors influencing vitamin D status, UVB exposure and BMI were significantly correlated with 25(OH)D, adjusted for season. The predictors were similarly associated with both serum level outcome variables, 25(OH)D3 and 25(OH)D.

Of note, latitude was not significantly correlated with adjusted 25(OH)D3 ($P = 0.20$) or raw 25(OH)D3 ($P = 0.15$). Also, UVB exposure explained 9% of the total variance in 25(OH)D3 and 25(OH)D values. While cutaneous synthesis, and latitude in particular, have been

Table 1
Correlation and stepwise regression of non-food variables associated with 25(OH)D and 25(OH)D3, adjusted for season ($N = 780$).[a]

Predictor variable	Adjusted 25(OH)D3 correlation (P value)	Adjusted 25(OH)D correlation (P value)	Adjusted 25(OH)D3 B coefficient (95% CI)	Adjusted 25(OH)D B coefficient (95% CI)
Weight (kg)	**−0.11 (0.003)**	**−0.10 (0.004)**	Excluded	Excluded
BMI	**−0.14 (<0.0001)**	**−0.14 (<0.0001)**	**−0.39 (−0.57, −0.21)**	**−0.37 (−0.55, −0.19)**
Age	0.05 (0.112)	0.06 (0.112)	–	–
Sex	0.03 (0.363)	0.03 (0.398)	–	–
Latitude	−0.05 (0.196)	−0.05 (0.136)	–	–
% work outside	**0.08 (0.029)**	**0.08 (0.032)**	**0.91 (0.14, 1.68)**	**0.86 (0.08, 1.63)**
Sun exposure	**0.18 (<0.0001)**	**0.17 (<0.0001)**	**0.04 (0.02, 0.06)**	**0.04 (0.02, 0.06)**
Tanning beds	**0.24 (<0.0001)**	**0.24 (<0.0001)**	**6.12 (4.21, 8.04)**	**6.01 (4.10, 7.92)**

[a] Bold face entries designate statistically significant correlations. Regression models were confined to participants for which there were valid values for all of the involved variables ($N = 640$).

thought to play key roles in vitamin D status, our results suggest that it is less important today than in previous times. This is perhaps due in part to the reduction in time spent outdoors, fear of the sun, or increased sunscreen use in today's society compared to previous generations [7].

These generally recognized non-food predictors of vitamin D status explained 13% of the total variance in 25(OH)D3 and 25(OH)D values. While usual food sources contribute only a small amount to vitamin D status, recently discovered meat sources could provide an explanation for the gap in vitamin D input [8]. Non-traditional foods should be investigated as possible undiscovered vitamin D sources.

Limitations of this study include the use of self-reported data, for which recall bias may have occurred. Also, sun exposure was not precisely measured but based on reported average daily time spent outdoors. Additionally, this cohort of individuals was self-selected for health consciousness and their results may not be generalizable to the general population.

In conclusion, although certain UVB exposures significantly contributed to vitamin D status, their ability to explain inter-individual variability was limited. Non-traditional food sources as possible vitamin D inputs need to be investigated further.

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Conflicts of interest

The authors have no conflicts of interest to disclose.

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