



Review

Quantifying the food sources of basal vitamin d input

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ABSTRACT

Cutaneous synthesis and traditional food sources do not fully account for unsupplemented vitamin D status. Non-traditional food sources may be an undiscovered input. 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 vitamin D status and selected food sources. Serum 25(OH)D concentration was adjusted for season, UVB exposures, and body size. These adjusted values were then regressed against multiple food items and combinations. Whole milk cottage cheese, eggs, red meat, and total protein were positively associated with total 25(OH)D and/or 25(OH)D3 ($P < 0.05$ for each), whereas fish and milk intake were not. The slope of the relationship was such that for every intake of 1 serving/day, serum 25(OH)D rose by about 2 ng/ml for eggs and 1 ng/ml for meat and total protein. For every weekly serving of whole milk cottage cheese, serum 25(OH)D rose by about 1 ng/ml. While some food sources were significant predictors of vitamin D status, their ability to explain inter-individual variability was limited. Supplementation will likely remain essential to improving vitamin D status on a population level.

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1. Introduction

Traditional food sources contribute <200 IU/day to vitamin D intake [1]. Heaney et al. demonstrated that non-supplemented adults have basal, all-source vitamin D inputs of about 2000 IU/day and based on seasonal variation, estimated that no more than 25% of that comes from cutaneous synthesis [2]. This leaves an undiscovered input of about 1000–1500 IU/day. Fish, eggs, and milk are known food sources of vitamin D [3–6]. Recent studies

have identified meat and poultry as additional sources [7,8]. These newly documented sources, along with other non-traditional foods may provide a possible explanation for the vitamin D input gap. Many studies have demonstrated that worldwide vitamin D intake is insufficient and dietary strategies are needed for the general population to achieve adequate vitamin D status [9–11]. Mixed results have been reported regarding the association between diet type and serum 25-hydroxyvitamin D [25(OH)D] levels [12,13]. Therefore, identifying specific food items that increase 25(OH)D serum levels will contribute to the development of these strategies. GrassrootsHealth (GRH), a non-profit public health research organization running a large population based study, has assembled a database with serum 25(OH)D measurements and information on vitamin D supplementation, demographics, and food intake. This

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study aimed to use GRH data to describe the relationship between serum 25(OH)D and food sources among non-supplement-taking participants aged 16 years and older.

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 (86% live in the United States or Canada) with highly diverse food intakes. 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 the number of servings ingested in the prior 7 days for a limited set of food items and other factors such as sun exposure and body size. 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 by ZRT Laboratory (Beaverton, OR). Both serum values were used because 25(OH)D3 is expected to be influenced by environmental factors, but 25(OH)D2 [contained within total 25(OH)D] is not.

2.3. Statistical methods

Serum 25(OH)D3 and 25(OH)D values were adjusted for seasonal influence and non-food variables using methods described in a companion paper [14]. The adjusted residuals were then regressed against intake of food items (model 1) and food items and

combinations (model 2). The slope of the relationship for weekly intakes was multiplied by 7 to determine the serum level change for each additional daily serving. 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. The mean age was 48 years (± 13) and 65% of the participants were female. Reported food intake among participants is described in Table 1.

Whole milk cottage cheese and total protein were significantly positively associated with serum 25(OH)D3 ($P=0.007$, $P<0.001$ respectively) and 25(OH)D ($P=0.008$, $P=0.001$ respectively). Red meat was positively associated with 25(OH)D3 ($P=0.041$) and eggs were associated with 25(OH)D ($P=0.007$). Coefficients and 95% confidence intervals are shown in Table 2. For each daily serving, serum levels rose by about 2 ng/ml for eggs and 1 ng/ml for meat and total protein. Serum levels rose by about 1 ng/ml for each weekly serving of whole milk cottage cheese. Other food items such as fish, milk, and low fat cottage cheese were not significantly associated.

Additional restricted intake models were created by excluding high intakes of significant food predictors (eggs, whole milk cottage cheese, total protein, and red meat) in a stepwise manner. In each case, the relationships between these food items and serum 25(OH)D values were stronger than with models that included all food intake amounts, indicating that the observed associations were not determined by outliers (data not shown).

About 3% of the total variance in vitamin D status was explained by food intake. The absolute standard deviation of unadjusted 25(OH)D was 13.6 ng/ml; after accounting for non-food factors it was 12.7 ng/ml and after food intake it was 12.5 ng/ml. The coefficient of variation around the mean for 25(OH)D was similar for non-supplement-taking participants (41.4%) and participants taking >2000 IU/day (41.3%).

Table 1
Reported food intake among non-supplement-taking adult participants ($N=780$).

Food Items (3 oz serving)	Median # servings (I–Q ^a range)	Food Items (8 oz serving)	Median # servings (I–Q ^a range)	Food Items (1 tbsp serving)	Median # servings (I–Q ^a range)
Hamburger/ground beef/pork	2 (4)	Non-fat milk	0 (0)	Olive oil	3 (6)
Other red meat	1 (2)	Low fat milk	0 (1)	Salad oil	0 (2)
Total red meat	3 (5)	Whole milk	0 (0)	Mayonnaise	1 (2)
Salmon	0 (1)	Total milk	2 (6)	Butter	3 (4)
Tuna	0 (1)	Eggs ^b	4 (4)	Cream cheese	0 (0)
Other fish	0 (1)	Fruit/vegetables ^b	14 (14)	Sour cream	0 (1)
Total fish	2 (3)				
Cheese	3 (4)				
Low/non-fat cottage cheese	0 (0)				
Whole milk cottage cheese	0 (0)				

^a I–Q is inter-quartile range.

^b Serving size is each for eggs and $\frac{1}{2}$ cup for fruit/vegetables.

Table 2
Stepwise regression of food variables and 25(OH)D3 and 25(OH)D residuals ($N=640$)^a.

Included predictor variables	25(OH)D3 B coefficient (95% CI)	25(OH)D3 serum level increase for 1 serving/day	25(OH)D B coefficient (95% CI)	25(OH)D serum level increase for 1 serving/day
Food items (model 1)				
Eggs	0.18 (–.01, 0.36)	1.3 ng/ml	0.24 (0.07, 0.41)	1.7 ng/ml
Whole milk cottage cheese	1.21 (0.33, 2.10)	1.2 ng/ml ^b	1.16 (0.28, 2.05)	1.2 ng/ml ^b
Red meat	0.15 (0.01, 0.30)	1.1 ng/ml	(excluded)	–
Food items and combinations (model 2)				
Total protein ^c	0.15 (0.07, 0.23)	1.1 ng/ml	0.14 (0.06, 0.23)	1.0 ng/ml
Whole milk cottage cheese	1.23 (0.34, 2.11)	1.2 ng/ml ^b	1.19 (0.31, 2.07)	1.2 ng/ml ^b

^a Bold face entries designate statistically significant associations ($P<.05$). Regression models were confined to participants for which there were valid values for all of the involved variables.

^b For whole milk cottage cheese, serum level increase is for 1 serving/week.

^c Total protein = red meat, fish and eggs.

4. Discussion

Among reported food intakes, whole milk cottage cheese and total protein were significantly associated with both 25(OH)D3 and 25(OH)D, red meat with 25(OH)D3, and eggs with 25(OH)D. The impact on serum level values was similar for both 25(OH)D3 and 25(OH)D for the food sources significantly associated with both outcome measures.

While dairy products are a known vitamin D source, our study points out a possible independent role of whole milk cottage cheese. A pilot study documented the protective effect of eating paneer (cottage cheese) with the risk of hip fracture, but a biologic measure of vitamin D was not assessed [15]. Also, the associations found between red meat and eggs and vitamin D serum levels support the findings of recent studies [3,4,7,8]. These food items should be investigated further as a possible vitamin D inputs.

Food sources explained about 3% of the total variance in 25(OH)D3 and 25(OH)D values. Since variation around the mean in these non-supplement takers is similar to those taking supplements, unexplained inter-individual variability in non-supplement-taking participants is not likely due to undiscovered inputs, but to intrinsic biological factors, such as differences in the rate of 25-hydroxylation and utilization, as well as measurement error.

Limitations of this study include use of self-report data where recall bias may have occurred and use of a food item questionnaire that was extensive but not comprehensive. Food fortification and items such as poultry, mushrooms, and milk substitutes (e.g. soy or almond beverage) were not assessed. Also, this cohort of individuals was self-selected for health consciousness and results may not be generalizable to the general population.

In conclusion, while certain food sources significantly contributed to vitamin D status, their ability to explain inter-individual variability was limited. It is likely that vitamin D supplementation will remain key to improving vitamin D status at a population level.

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Conflicts of interest

The authors have no conflicts of interest to disclose.

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