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No Relationship Between Serum 25(OH) Vitamin D Concentrations and Perceptions of Vitamin D Dietary Intake Adequacy in US and German Adults Not Using Dietary Supplements

Regan L. Bailey, Sowmyanarayanan V. Thuppal, Katherine D. Sherif, Nigel Denby, Suzanne R. Steinbaum, Bryan Haycock, Alexandra E. Cowan, Jared R. Nieters, and Clemens von Schacky

Introduction

Vitamin D plays an important role in bone health, cancer, and cardiovascular disease [1–12]. Some [13, 14] but not all studies [15] have associated optimal serum vitamin D with lower risk for mortality. Thus, vitamin D has increasingly become a

R. L. Bailey (✉) · S. V. Thuppal · A. E. Cowan
Department of Nutrition Science, Purdue University, West Lafayette, IN, USA
e-mail: reganbailey@purdue.edu; cowan9@purdue.edu

K. D. Sherif
Jefferson Women's Primary Care, Philadelphia, PA, USA
e-mail: Katherine.sherif@jefferson.edu

N. Denby
Grub4Life and People Matter TV, London, UK
e-mail: nigel@buddypower.net

S. R. Steinbaum
Women and Heart Disease Center, New York, NY, USA

B. Haycock
Department of Nutrition and Integrative Physiology, University of Utah, Salt Lake City, UT, USA
e-mail: bryan.haycock@utah.edu

J. R. Nieters
Mapleworks, LLC, Amissville, VA, USA

C. von Schacky
University of Munich, Munich, Germany
e-mail: clemens.vonschacky@med.uni-muenchen.de

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focus of medical research that links nutrition and preventative medicine. The Academy of Nutrition and Dietetics recommends a balanced diet with a variety of nutrients for achieving optimal dietary intakes [16]. Unfortunately, vitamin D is not naturally found in large quantities in contemporary dietary patterns. For this reason, vitamin D is used to fortify many foods (e.g., milk, breakfast cereals, and orange juice) in the USA. However, vitamin D fortification is not routine practice in Germany. Without fortification and dietary supplement use, many people in both countries do not achieve the dietary recommendations [17–22].

Previously, a study on perceptions of a healthy diet among US and German adults showed that 84% of the adults believed that vitamin D was critical for optimal health [23]. Despite the relatively high use of vitamin D dietary supplements (62% in the USA and 31% in Germany), more than half were unsure or did not think they consumed enough vitamin D in their diet [23]. However, this study did not measure serum 25 (OH) vitamin D concentrations relative to these perceptions. Therefore, the purpose of the current study is to compare the knowledge and perceptions of vitamin D adequacy in the diet with the biomarker of vitamin D exposure in these two populations with (USA) and without (Germany) vitamin D fortification among adults who were not using dietary supplements.

Methods

A clinical study of US and German adults was conducted in the spring of 2016 at Purdue University through the Indiana Clinical and Translational Science Institute and the Department of Nutrition Science (USA) and at Ludwig Maximilians-Universität München, Munich, and in clinical sites at Jena, Meerbusch, Hamburg, and Hannover (Germany). The study protocol was approved by IRBs at both universities. Inclusion criteria included nonpregnant, non-lactating adults, 18–80 years not currently using dietary supplements, and without any acute health conditions.

At a clinic visit, baseline demographic details were obtained including age, sex, race/ethnicity, educational attainment, income, physical activity, and duration of exposure to sunlight. Height and weight were measured using calibrated instruments, and body mass index was calculated using the standard formula weight (kg)/height (m) [2]. Dietary knowledge and perceptions of vitamin D intake were assessed using a questionnaire that consisted of close-ended questions with dichotomous, ordinal, and Likert scale response options modified after a previous study [23]. In this questionnaire, a balanced diet was defined as “a diet with all the recommended daily intake of nutrients,” and specific questions were included to understand the perceptions about foods that contain vitamin D, adequacy of vitamin D in diet, and importance of vitamin D for health.

Non-fasting blood samples were collected using red-top vacutainer tubes and assayed for serum 25 (OH) vitamin D using the LC-MS/MS method. Based on the National Academies of Science, Engineering, and Medicine (NASEM) 2011 recommendations, serum vitamin D concentrations were classified as “inadequate” at

<20 ng/mL (<50 nmol/L) [24]. Heany and Holick have suggested <30 ng/mL (<75 nmol/L) as a marker for "suboptimal" vitamin D concentrations [25]. Both cut points were examined for this analysis.

Statistical analyses were performed using SAS statistical software 9.4 by SAS Institute Inc., Cary, NC, USA. Demographic and biomarker data were summarized with descriptive statistics. Dietary perceptions were compared based on vitamin D status cut-point categories defined as inadequate and suboptimal. ANOVA and t-tests were used for continuous variables and chi-square tests for categorical variables with statistical significance set at a p-value <0.05.

Results

In both countries, there was a higher proportion of women than men in the sample; the German sample was comprised exclusively of non-Hispanic Whites, whereas slightly more racial diversity existed in the US sample (Table 20.1). Participants in Germany were, on average, older than participants in the USA. The majority of the sample had a college education and reported some physical activity; however, the frequency of exercise was higher in the USA than in Germany. In both countries, minutes of sunlight (i.e., UV exposure) was higher on the weekends than the weekdays but did not differ by country. While the mean BMI was in the healthy range (18–25 kg/m^2), the prevalence of overweight and obesity together was 40%.

Based on the 2011 National Academies of Science, Engineering, and Medicine (NASEM) recommendations, the mean serum 25(OH)D concentrations for both the USA (28 ng/mL) and Germany (23 ng/mL) fall within the optimal range of 20 ng/mL to 50 ng/mL [24]. American adults had higher mean 25(OH)D concentrations and therefore lower prevalence of inadequate or suboptimal 25(OH)D. Mean 25(OH)D did not differ by sex, BMI, education, age, or income within country (data not shown).

All participants reported that consuming a balanced diet is important (Table 20.2). Overall, half the sample rated their diet as good, and equal proportions (~25%) rated their diet as very good/excellent and fair/poor. These percentages changed however when participants rated if their diet was balanced with 45% agreeing, 38% disagreeing, and 17% who were unsure. Similarly, more participants did not know or were unsure (64%) if their diets were adequate in vitamin D.

Interestingly when country data were combined or stratified, mean 25(OH)D concentrations did not differ based on perceptions of a balanced diet, ratings of diet, adequacy of vitamin D in the diet, or importance of vitamin D for health. A higher proportion of adults were inadequate who thought vitamin D was only "somewhat important" for health compared to "important" and "very important," who did not differ—but since the sample size was small (n = 5), this should be interpreted with caution. None of the findings in Table 20.2 were significant when we examined response options with the prevalence of suboptimal serum 25(OH)D concentrations (data not shown).

Table 20.1 Demographic characteristics and mean serum 25(OH) vitamin D [25(OH)D] of US and German adults (> 18 years, $n = 200$) participating in a cross-sectional study on the knowledge and perceptions of dietary vitamin D[a,b]

	All ($n = 200$)	USA ($n = 100$)	Germany ($n = 100$)	p-value
Race/ethnicity, %[c]				<0.0001
Non-Hispanic White	86	69	100	
Non-Hispanic Black	1	2	0	
Hispanic	6	11	0	
Asian	7	15	0	
Age in years, mean (range)	35 (18–80)	29 (18–71)	40 (18–80)	<0.0001
Education, %[c]				<0.0001
High School or equivalent	21	10	32	
Associate degree or some college	13	20	5	
College graduate or higher	66	70	62	
Income[c]				0.90
<50,000 USD	53	51	54	
>50,000 USD	45	44	45	
Frequency of Physical activity, %				<0.0001
None	13	0	27	
1–2 days a week	39	28	49	
3–4 days a week	36	51	21	
> 4 days/week	12	21	3	
Mean sunlight exposure, minutes (95% CL)				
Weekdays	80 (71–98)	85 (71–98)	77 (61–94)	0.48
Weekends	172 (155–188)	164 (142–186)	181 (157–205)	0.30
Mean BMI, kg/m^2 (95% CL)	24 (23.8–25.1)	25 (24.1–26.0)	24 (23.4–24.7)	0.08
Prevalence overweight, %	30	33	28	0.25
Prevalence of obesity, %	10	13	6	0.09
Mean 25 (OH)D, ng/mL (95% CL)	25.4 (24.0–26.8)	27.7 (25.5–29.9)	23.1 (21.4–24.7)	0.001
Prevalence of inadequacy (%)	27	17	36	0.002
Prevalence of suboptimal (%)	76	70	82	0.047

[a]Non-fasting blood samples were assayed for serum 25(OH) vitamin D using the LC-MS/MS method

[b]Comparison by country was performed with t-tests for continuous variables (means) and chi-square tests for categorical variables (percentages); significance set at $p < 0.05$

[c]Percentages do not equal 100 as missing data and small response options are not presented

Table 20.2 Mean (95% CL) serum 25(OH) vitamin D concentrations by sex and dietary perceptions of vitamin D intake in US and German adults over 18 years of age ($n = 200$)[a,b,c]

	% of sample	Mean 25(OH)D (95% CI)	% (SE) inadequate	% (SE) inadequate	
				USA	Germany
How important is a balanced diet?					
Somewhat important	25	23.3 (20.5–26.1)	31 (6)	25 (7)	35 (12)
Important	43	25.5 (23.4–27.6)	28 (5)	16 (6)	39 (7)
Very important	32	27.1 (24.7–29.5)	20 (5)	10 (7)	29 (8)
How would you rate your diet?					
Excellent/very good	24	25.9 (23.1–28.8)	20 (6)	10 (8)	31 (9)
Good	50	25.7 (23.8–27.7)	25 (4)	16 (5)	35 (7)
Fair/poor	26	24.2 (21.4–26.9)	35 (6)	25 (7)	46 (9)
Do you have a nutritionally balanced diet?					
Yes	45	25.6 (23.5–27.6)	26 (5)	12 (5)	41 (8)
No	38	25.0 (22.8–27.2)	28 (5)	21 (6)	34 (8)
Don't know	17	25.8 (22.4–29.3)	23 (8)	22 (13)	29 (10)
How important is vitamin D for overall health?					
Somewhat important	8	23.1 (18.2–28.1)	40 (11)	60 (16) [1]	36 (15)
Important	27	24.9 (22.2–27.6)	32 (6)	20 (8) [2]	42 (8)
Very important	65	25.9 (24.1–27.6)	23 (4)	13 (4) [2]	33 (7)
Do you get enough vitamin D from your diet?					
Yes	36	26.1 (23.7–28.4)	26 (5)	16 (5)	36 (10)
No	37	25.6 (23.3–27.9)	23 (7)	17 (7)	29 (7)
Don't know	27	24.2 (21.6–26.9)	32 (6)	19 (8)	44 (8)
Do these food sources contain vitamin D?					
Milk[d]					
Yes	63	25.9 (24.1–27.7)	27 (4)	16 (4)	39 (7)
No	36	24.7 (22.2–27.1)	25 (5)	22 (9)	32 (7)
Oily fish[d]					
Yes	28	25.6 (22.8–28.3)	27 (6)	25 (9)	33 (8)
No	71	25.4 (23.7–27.0)	25 (4)	15 (4)	36 (6)

[a]Non-fasting blood samples were collected using red-top vacutainer tubes and assayed for serum 25(OH) vitamin D using the LC-MS/MS method

[b]Mean serum 25(OH)D and prevalence of inadequacy compared using a general linear model controlled for country of participant

[c]Estimates with numerical superscripts differ significantly at $p < 0.05$. All other estimates do not significantly differ

[d]Percentages do not equal 100 as "don't know" options are not presented

Despite low reports of nutritionally balanced diets among US and German participants, most considered vitamin D as an important nutrient in improving joint and bone health (including osteoporosis) (74% and 65%). Participants in both the USA and Germany identified milk (82% and 44%) and cheese (70% and 40%) as the top two food sources of vitamin D. While German participants also reported oily fish as the third highest food source, Americans ranked eggs as the third most common source of vitamin D in their diets (Fig. 20.1).

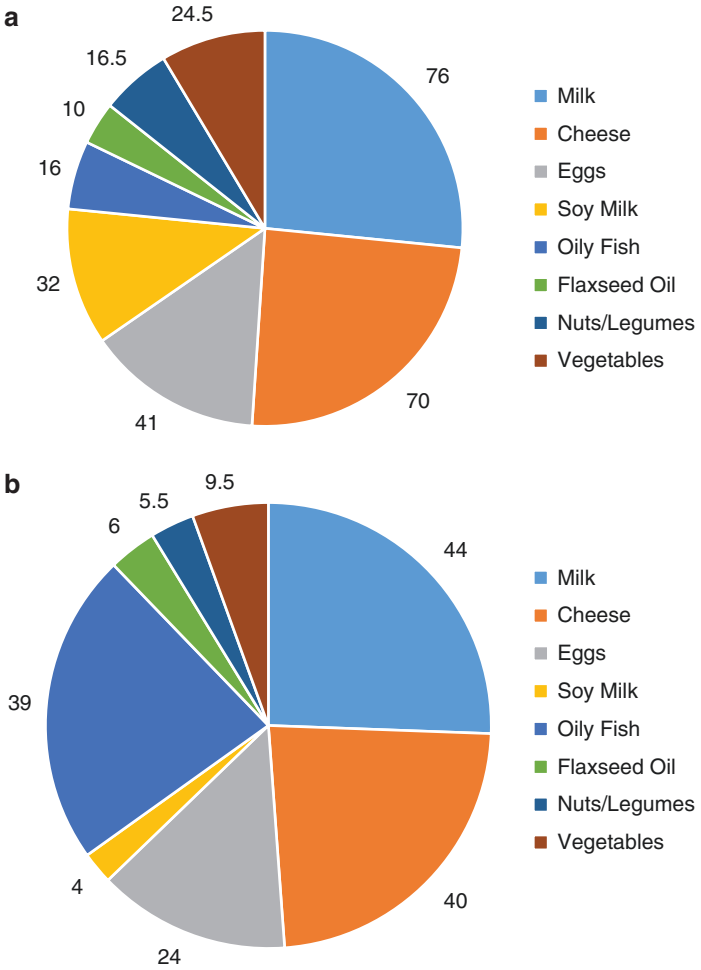

Fig. 20.1 Proportion of participants identifying food sources of vitamin D in the United States (Panel **a**) and Germany (Panel **b**) (n = 200)

Discussion

Many adults, regardless of country, correctly identified some food sources for vitamin D and had knowledge of the bone health benefits of vitamin D. A minority (36%) thought they have adequate amounts of vitamin D in their diet; but, a higher proportion (78%) actually had "adequate" serum 25(OH)D concentrations based on the National Academies of Science, Engineering, and Medicine (NASEM) guidelines. When an optimal cut point was applied, prevalence estimates based on serum increased on both countries but especially for the USA. Stated differently, 64% of adults were unsure or did not think they consumed enough vitamin D in the diet,

whereas 27% were inadequate and 76% were suboptimal when serum concentrations were examined. Thus the choice of cut points for nutritional biomarkers is quite important and influences the prevalence estimates [26–28]. Indeed, considerable debate exists for the appropriate cut point to use for assessment of vitamin D status in the blood [25, 29]. It is important to note that not only is a low vitamin D of concern but also a high vitamin D concentration as a U- and J-shaped risk curve exists for vitamin D status and health outcomes [13, 14], so use of one cut point alone may not be optimal for those wishing to examine the high ends of the distribution.

When comparing serum 25(OH)D concentrations between countries, a higher percentage of US participants had adequate vitamin D status when compared to participants in Germany. In the USA, many foods are fortified with vitamin D; however, in Germany, fortification of food with vitamin D is not permitted. Previous European studies suggest that vitamin D fortification may have a positive impact on vitamin D intakes in European countries [30, 31]. In the USA, where fortification practices are regularly used, the mean serum 25(OH)D concentrations were on average 5 ng/mL higher than in Germany, suggesting that this higher average intake of vitamin D may be due to US fortification practices. None of the participants in this study used dietary supplements containing vitamin D, and UV exposure patterns did not differ, so the lower concentrations may be due to differences in fortification practices and food choices within country.

Strengths and Limitations

This is the only study to our knowledge that compares dietary perceptions and biomarker concentrations together for vitamin D. Serum 25(OH)D is the most accurate and reliable marker for vitamin D exposure, and the analytical method used in this study is traceable to the National Institutes for Standards and Technology, Standard Reference Material, which is critical to harmonize the method used to assess vitamin D in this study [32, 33]. The chief limitation of the current study is the use of convenience sampling. Our participants were relatively well-educated and lacked in racial and ethnic diversity. While the vitamin D status data in the US sample was similar to that from the National Health and Nutrition Examination Survey (NHANES) 2007–2010 (26 ng/mL) with 17% of individuals having vitamin D levels below 20 ng/mL, the vitamin D status in our German subjects was substantially higher than nationally representative data from the German Health Interview and Examination Survey for Adults (DEGS1) 2008–2011, where the mean serum level in adults was approximately 18 ng/mL in men and 20 ng/mL in women. However, it is important to note that our study and the NHANES used different analytical methods (LC-MS/MS) than DEGS1 (chemiluminescence immunoassay) for measuring for vitamin D, which may account, in part, for some the difference between our German sample and the DEGS1 study. LC-MS/MS is considered the gold standard method for testing for vitamin D [32, 33]. Our study was conducted prior to peak summer months, and serum 25(OH)D concentrations are known to vary by season of collection [34, 35].

Conclusions

Mean concentrations were lower, and the prevalence of inadequacy and suboptimal 25(OH)D was higher in Germany than in the USA. Most adults rated vitamin D as important for bone health; but, fewer Germans (22%) than US adults (50%) perceived their diet as adequate in vitamin D. Mean 25(OH)D concentrations and risk of vitamin D inadequacy did not differ by perceptions of dietary adequacy, ratings of a balanced diet, knowledge of vitamin D food sources, or by rankings of importance of vitamin D for health. Fortification with vitamin D in the USA may explain the higher 25(OH) concentrations as UV exposure, and BMI did not differ, and no participants were using dietary supplements. Perceptions and knowledge of vitamin D were not related to the biomarker of vitamin D status in either group.

Author Contributions RLB, CvS, KDS, ND, SRS, and BH conceived and designed the study; SVT and CvS performed all study procedures; SVT and AEC analyzed the data; RLB, SVT, and AEC wrote the paper. JN and AEC reviewed and edited the paper and prepared data presentation. All authors read and approved the final version of the manuscript.

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