Effect of Latitude on Vitamin D Levels

Patrick F. Leary, DO, MS; Ina Zamfirova, MS; Johnathan Au, MPH; Ward H. McCracken, DO

From the Lake Erie College of Osteopathic Medicine in Erie, Pennsylvania (Dr Leary); the Russell Research Institute at Lutheran General Hospital in Downers Grove, Illinois (Ms Zamfirova and Mr Au); and the University of Minnesota in Minneapolis (Dr McCracken).

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Address correspondence to Patrick F. Leary, DO, MS, 5401 Peach St, Suite 3400, Erie, PA 16509-2601.

E-mail: pleary@lecom.edu

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Context: Vitamin D levels have been linked to bone health and to numerous diseases; however, an element that lacks substantial direct data and limits the evidence basis regarding whom to screen for vitamin D deficiency is the effect of latitude on vitamin D levels.

Objectives: To determine whether latitude influences vitamin D levels and to investigate the influence of other factors that may affect vitamin D levels, including sex, race, skin type, and body mass index.

Methods: Osteopathic medical students were recruited from campuses in Bradenton, Florida, and Erie, Pennsylvania. Surveys were administered to obtain demographic information, and blood samples were drawn to measure total vitamin D levels. Two-sample *t* tests, Fisher exact test, and logistic regression was used to assess differences in total vitamin D levels between the 2 locations.

Results: A total of 359 medical students (aged 22-57 years) were included in the study, 194 at the Bradenton campus and 214 at the Erie campus. The mean (SD) vitamin D level was 34.5 (11.8) ng/mL among participants in Bradenton and 28.1 (12.4) ng/mL among participants in Erie. Logistic regression models revealed an adjusted OR of 3.3 (95% CI, 1.73-6.4) for deficient total vitamin D among Erie students. Non-white race, male sex, and high body mass index were also statistically significant risk factors for vitamin D deficiency in regression models (P<.05).

Conclusion: Latitude was found to be a statistically significant risk factor for vitamin D deficiency. Additionally, the findings suggest that persons with darker skin tone and, to a lesser degree, men and persons who are overweight or obese are also at increased risk for vitamin D deficiency. Physicians should be cognizant of these risk factors when deciding whom to screen.

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Numerous studies have implicated vitamin D deficiency in maladies such as cancer, poor bone health, poor orthopedic surgical outcomes, fractures in elderly persons, diabetes, heart disease, osteoporosis, autoimmune disorders, multiple sclerosis, schizophrenia, and depression.[1-8] Studies have even linked vitamin D intake to general and musculoskeletal health in special populations, such as athletes.[9] One study found that deficient and insufficient vitamin D levels are highly prevalent among participants in the NBA draft.[10] Systematic reviews and meta-analyses did not show clear evidence that correction of low serum vitamin D level improves outcomes.[11] Despite having several supplement guidelines to safely and effectively manage vitamin

Table 1.
Student Demographics at Bradenton, Florida, and Erie, Pennsylvania, Campuses of Lake Erie College of Osteopathic Medicine[a]

Demographic	Bradenton	Erie	*P* Value
Race	n=194	n=214	.066
White	149 (76.8)	169 (79.0)	
Asian	14 (7.2)	16 (7.5)	
Indian	4 (2.1)	10 (4.7)	
Other	25 (12.9)	13 (6.1)	
Unknown	2 (1.0)	6 (2.8)	
Sex	n=194	n=214	.062
Female	105 (54.1)	96 (44.9)	
BMI	n=192	n=211	.004
Underweight	1 (0.5)	5 (2.4)	
Normal	139 (72.4)	121 (57.4)	
Overweight	44 (22.9)	63 (29.9)	
Obese	8 (4.2)	22 (10.4)	
Skin Type Grade[b]	n=193	n=213	.461
I	8 (4.2)	17 (8.0)	
II	71 (36.8)	76 (35.7)	
III	88 (45.6)	94 (44.1)	
IV, V, or VI	26 (13.5)	26 (12.2)	
Tanning Bed Use	n=194	n=211	.021
Yes	188 (96.9)	192 (91.0)	
No	6 (3.1)	19 (9.0)	
Excessive Tanning	n=194	n=214	.727
Yes	3 (1.6)	5 (2.3)	
No	191 (98.5)	209 (97.7)	
Sun Block Use Frequency	n=176	n=131	.001
Never	22 (11.3)	0	
Rarely	33 (17.0)	27 (20.6)	
Occasionaly	40 (20.6)	33 (25.2)	
Usually	55 (28.4)	50 (38.2)	
Always	26 (13.4)	21 (16.0)	
Not Applicable	18 (9.3)	0	

(continued)

D deficiency, there is no established consensus regarding whom to screen. Part of the difficulty is that many variables have been demonstrated in the literature to play a role in affecting levels of vitamin D. For example, obese persons were found to have significantly lower vitamin D levels, likely resulting from a reduced bioavailability due to vitamin D's fat-soluble nature.[12] A longitudinal study[13] found that a greater amount of melanin is correlated with reduced capacity of the skin to synthesize vitamin D. Yet, one variable that has been recognized to affect vitamin D levels but for which current literature lacks consensus is latitude. Holick[14] suggested that sunlight in the winter months north of 37° is insufficient to produce adequate vitamin D synthesis. An Australian study[15] concluded that although latitude and season had an effect on vitamin D levels, other factors, such as behavior, had a much larger effect. Another study by Holick[5] found no connection between latitude and serum vitamin D levels,[5] whereas Jelinek et al[16] found a significant correlation between latitude and vitamin D levels in patients with multiple sclerosis.

The present study was conducted to compare vitamin D levels in medical students at 2 campuses of the Lake Erie College of Osteopathic Medicine: Bradenton, Florida (27°N), which has an average of 101 clear days of sun per year, and Erie, Pennsylvania (42°N), which has an average of 63 clear days of sun per year.[18] These locations had closely matching populations, allowing for a more focused comparison of the effects of latitude on serum vitamin D levels. As a secondary outcome, other factors that were known to correlate with vitamin D levels, specifically sex, race, skin type, and body mass index (BMI), were compared.

Methods

Data were collected from second-year medical students at the Lake Erie College of Osteopathic Medicine (LECOM) on campuses in Bradenton, Florida, and Erie, Pennsylvania, during their annual phlebotomy laboratory training from February to March 2011 and again from February to March 2012. All second-year medical students attending either campus were eligible to participate. Participation was voluntary, and no compensation was provided. The study was made known to all students via direct presentation during their required phlebotomy training in the second year. Once consent was received, participants were given surveys to elicit further demographic information before having blood collected. All blood draws were overseen by trained study coordinators and sent to a laboratory for 25-hydroxy vitamin D analysis (D_2, D_3, and total 25 (OH)D levels with ng/mL units).

To limit potential bias and confounding factors, participants were excluded from the study if any of the following were met: history of renal disease, bone disease, dermatologic conditions interfering with vitamin D synthesis, or cancer; use of exogenous vitamin D supplementation (≥800 IU daily); or excessive tanning (≥1 time per month).

The primary outcome of interest was the average levels of 25(OH)D in students between the campuses and their relationship to latitude. We acknowledge that literature has recognized deficient, insufficient, and sufficient ranges of vitamin D[10-12]; however, for the purposes of this study's data analysis, levels were dichotomized to be either *deficient* or *nondeficient*, with deficient being recognized as less than 20 ng/mL. Other covariates analyzed included BMI, medical history, current medications, use of tanning beds, use of sunscreen and strength applied, and skin type. Participants classified as underweight (BMI <18.5) were excluded because of low numbers. Participants classified as overweight (BMI 25-30) or obese (BMI ≥30) were collapsed into a single category, also owing to low numbers. Skin type was graded on the Fitzpatrick scale and was self-determined by participants. Types IV through VI were grouped together in data analysis because of low numbers.

Descriptive statistics for all continuous (mean [SD]) and categorical (No. [%]) data were calculated on all participant characteristics. A 2-sample *t* test for continuous and the Pearson χ^2 or Fisher exact tests for categorical data were performed to assess the significance between group means and proportions, respectively. Multiple logistic regression was used to calculate ORs and 95% CIs. Statistical significance was set at $\alpha = .05$. Analysis was conducted using STATA statistical software (version 11.2; Stata Corp).

Table 1 (continued).
Student Demographics at Bradenton, Florida, and Erie, Pennsylvania, Campuses of Lake Erie College of Osteopathic Medicine[a]

Demographic	Bradenton	Erie	*P* Value
Vitamin D Supplements	n=194	n=214	.014
Yes	10 (5.2)	26 (12.2)	
No	184 (94.9)	188 (87.9)	
Previous Related Disease	n=194	n=214	.734
Yes	2 (1.0)	3 (1.4)	
No	192 (99.0)	211 (98.6)	
BMI, mean (SD)	23.7 (3.2)	24.7 (4.2)	.005
SPF, mean (SD)	20.1 (18.9)	15.0 (16.9)	.005
Total Vitamin D, mean (SD)	34.5 (11.8)	28.1 (12.4)	<.001

[a] Tables represent data for all people surveyed who gave complete answers to the participation questionnaire (including those who eventually met study exclusion criteria and were not part of the final data analysis). The n provided for each item represents the number of respondents from each school for that item.
[b] Fitzpatrick scale.

Abbreviations: BMI, body mass index; SPF, sun protection factor.

Results

Among the pool of 413 possible participants, 408 (98.8%) elected to participate in the study. However, 49 (13%) were excluded: 5 with medical conditions that affected vitamin D levels, 36 for exogenous vitamin D supplementation, and 8 for high tanning frequency. The final study population included 359 participants (aged 22-57 years), 194 at the Bradenton campus and 214 at the Erie campus. In the Bradenton cohort, 18 participants (5%) were found to be deficient in vitamin D, and in the Erie cohort, 49 participants (13%) were found to be deficient.

Participant demographics are presented in Table 1. The majority of participants were white, and the

Table 2.
Mean Total Vitamin D Levels for All Students and by Lake Erie College of Osteopathic Medicine Campus (Bradenton, Florida, and Erie, Pennsylvania)[a]

	Both Campuses			Bradenton			Erie		
Variable	n	Total Vitamin D, Mean (SD)	*P* Value	n	Total Vitamin D, Mean (SD)	*P* Value	n	Total Vitamin D, Mean (SD)	*P* Value
Sex			<.001			<.001			<.001
Female	192	35.5 (13.5)		105	38.1 (12.4)		87	32.4 (14.3)	
Male	202	27.2 (9.9)		89	30.3 (9.4)		113	24.8 (9.7)	
Race			<.001			<.001			.036
White	306	33.0 (12.1)		149	36.9 (10.7)		157	29.4 (12.3)	
Asian	30	23.8 (13.1)		14	22.9 (10.5)		16	24.7 (15.4)	
Indian	14	24.0 (10.8)		4	16.0 (7.2)		10	27.2 (10.6)	
Other	36	26.7 (12.1)		25	29.8 (11.9)		11	19.5 (9.5)	
Unknown	8	24.4 (10.2)		2	35 (14.1)		6	20.8 (6.8)	
BMI			<.001			.036			.097
Underweight	5	38.2 (23.0)		1	40 (0.0)		4	37.8 (26.5)	
Normal	254	33.0 (12.5)		139	36.0 (11.1)		115	29.3 (13.2)	
Overweight	102	28.7 (11.6)		44	31.7 (13.1)		58	26.5 (9.8)	
Obese	28	25.0 (10.9)		8	26.9 (10.9)		20	24.2 (11.1)	
Skin Type Grade[b]			<.001			<.001			.166
I	24	31.6 (13.6)		8	39.4 (10.6)		16	27.7 (13.5)	
II	142	34.7 (11.4)		71	39.3 (10.1)		71	30.0 (10.8)	
III	175	30.7 (12.9)		88	33.5 (11.1)		87	28.0 (14.0)	
IV, V, or VI	51	23.5 (10.1)		26	23.5 (10.8)		25	23.5 (9.5)	
Tanning Bed Use			.001			.140			<.001
Yes	25	39.0 (13.2)		6	41.5 (7.1)		19	38.3 (14.7)	
No	366	30.8 (12.3)		188	34.3 (11.8)		178	27.0 (11.8)	
Excessive Tanning			<.001			.088			<.001
Yes	8	46.4 (13.9)		3	46.0 (4.6)		5	46.6 (18.1)	
No	386	30.9 (12.3)		191	34.3 (11.8)		195	27.6 (12.0)	
Sunscreen Use			.009			<.001			.743
Never	22	30.2 (10.9)		22	30.2 (10.9)		0	…	
Rarely	60	27.7 (12.0)		33	28.3 (11.1)		27	27.0 (13.1)	
Occasionally	69	35.3 (13.9)		40	39.3 (9.9)		29	29.8 (16.7)	
Usually	102	33.9 (12.3)		55	36.9 (12.2)		47	30.5 (11.5)	

(continued)

Table 2 (continued).
Mean Total Vitamin D Levels for All Students and by Lake Erie College of Osteopathic Medicine Campus (Bradenton, Florida, and Erie, Pennsylvania)[a]

	Both Campuses			Bradenton			Erie		
Variable	n	Total Vitamin D, Mean (SD)	*P* Value	n	Total Vitamin D, Mean (SD)	*P* Value	n	Total Vitamin D, Mean (SD)	*P* Value
Always	46	33.5 (12.1)		26	36.7 (11.6)		20	29.4 (11.6)	
Not applicable	18	30.1 (9.7)		18	30.1 (9.7)		0	…	
Vitamin D Supplements			.015			.009			.032
Yes	35	36.2 (12.4)		10	43.9 (14.9)		25	33.1 (10.1)	
No	359	30.8 (12.4)		184	34.0 (11.4)		175	27.4 (12.6)	
Previous Related Disease			.648			.432			.180
Yes	5	33.8 (9.2)		2	28.0 (1.4)		3	37.7 (10.6)	
No	389	31.2 (12.6)		192	34.6 (11.8)		197	27.9 (12.4)	
BMI Correlation Coefficient (*r*)	389	–0.230	<.001	192	–0.256	.412	197	–0.168	.018
SPF Correlation Coefficient (*r*)	384	0.135	.008	192	0.153	.034	192	0.042	.561

[a] Tables represent data for all people surveyed who gave complete answers to the participation questionnaire (including those who eventually met study exclusion criteria and were not part of the final data analysis).
[b] Fitzpatrick scale.

Abbreviations: BMI, body mass index; SPF, sun protection factor.

proportion of white participants was similar between locations. A greater proportion of women participated in Bradenton (105 [54.1%]) compared with Erie (96 [44.9%]). Most participants were of normal weight, with the mean (SD) BMI being 23.7 (3.2) and 24.7 (4.2) for Bradenton and Erie, respectively. Most participants' skin type was categorized as either II (147 [36%]) or III (182 [45%]). The mean (SD) total vitamin D levels were 34.5 ng/mL (11.8) and 28.1 ng/mL (12.4) for Bradenton and Erie, respectively.

Mean total vitamin D levels are reported in **Table 2** for all study participants and by location. Participants who were female, white, or normal weight had higher mean total vitamin D levels. These trends were consistent for both locations. With regard to skin type classification, among participants in Bradenton, participants with darker skin types had lower vitamin D levels on average. Among participants in Erie, the highest vitamin D levels were observed for participants with type II skin. Lowest vitamin D levels were seen among those with type IV skin for either location.

Multivariate logistic regression results are presented in **Table 3**. Results demonstrate higher odds of deficient vitamin D levels among participants who were male, nonwhite, overweight/obese, and living in Erie. Statistical significance was only observed with regard to race and location. Skin type II and III showed decreased odds of vitamin D deficiency, whereas type IV showed increased odds. Only type II was found to be statistically significant.

Discussion

When controlled for other confounding variables, students at the Bradenton campus had statistically significant

Table 3.
Multivariate Logistic Regression for Students With Deficient Vitamin D Levels in Bradenton, Florida, Compared With Erie, Pennsylvania

Variable	OR (95% CI)	*P* Value
Campus		
Bradenton	1	
Erie	5.23 (2.27-12.04)	<.001
Race		
White	1	
Other	2.92 (1.08-7.83)	.034
Sex		
Female	1	
Male	2.18 (0.93-5.12)	.073
BMI		
Normal	1	
Overweight	1.06 (0.97-1.17)	.203
Skin Type Grade[a]		
I	1	
II	0.15 (0.03-0.65)	.011
III	0.49 (0.13-1.86)	.295
IV, V, or VI	1.23 (0.22-6.90)	.813
Tanning Bed Use		
No	1	
Yes	0.31 (0.03-2.77)	.292

[a] Fitzpatrick scale.

Abbreviation: BMI, body mass index.

higher vitamin D levels. Given how closely matched the sample populations were in demographics, this finding lends substantial evidence to the hypothesis that latitude is a primary risk factor for vitamin D deficiency. It should be noted that mean levels in participants from both campuses were both in the nondeficient range.

The secondary outcomes were generally consistent with existing literature. Although it did not achieve statistical significance, the breakdown by sex consistently showed higher average vitamin D levels in women at both campuses. Results of the race and skin type subcategories also showed similar results to those in the literature.[19] As skin complexion darkens, vitamin D levels decrease; people with lighter skin have overall higher levels of vitamin D.[13] Regarding BMI, it has been shown in other studies that BMI has an inverse relationship to vitamin D levels, and this study is in general agreement with that model.[12]

Several limiting factors that were difficult to plan and control for should be noted. Our sample population was one of convenience and, as such, represents a much younger segment of the overall population. Our data were likely skewed by the large proportion of the sample population being white, allowing few data points for Asian, Indian, and those categorized as "other." Additionally, the limited number of data points available for participants with darker skin types limits the power of the study to make any conclusive findings with regards to those participants. Further research could also help substratify risk in nonwhite races.

Dietary intake differences were not controlled for, and while sunscreen use was included in the preenrollment survey, it proved difficult to meaningfully quantify and control for in our analysis and so was omitted from the final analysis.

Given the warmer temperatures in Bradenton during the winter months, residents are more likely to be outside more often and have their skin exposed to the sun than residents of Erie during the same months.

Conclusion

Although all confounding factors were difficult to control for, this study found good preliminary evidence that living at a higher latitude and self-identifying as a race other than white are risk factors for vitamin D deficiency in the studied population. Male sex was found to be a higher-risk group; further research could help clarify this risk relationship. We suggest that physicians consider testing patients for vitamin D deficiency if they have appropriate symptoms and if they are a nonwhite race, if they live at higher latitudes, and, to a lesser degree, if they are overweight or obese.

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Author Contributions

All authors provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; all authors drafted the article or revised it critically for important intellectual content; all authors gave final approval of the version of the article to be published; and all authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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