Impact of Vitamin D Deficiency on the Productivity of a Health Care Workforce

Gregory A. Plotnikoff, MD, MTS, Michael D. Finch, PhD, and Jeffery A. Dusek, PhD

Objective: To define the relationship between vitamin D status and employee presenteeism in a large sample of health care employees. **Methods:** Prospective observation study of 10,646 employees of a Midwestern-integrated health care system who completed an on-line health risk appraisal questionnaire and were measured for 25-hydroxyvitamin D. **Results:** Measured differences in productivity due to presenteeism were 0.66, 0.91, and 0.75 when comparing employees above and below vitamin D levels of 20 ng/mL, 30 ng/mL, and 40 ng/mL, respectively. These productivity differences translate into potential productivity savings of 0.191%, 0.553%, and 0.625%, respectively, of total payroll costs. **Conclusions:** Low vitamin D status is associated with reduced employee work productivity. Employee vitamin D assessment and replenishment may represent a low-cost, high-return program to mitigate risk factors and health conditions that drive total employer health care costs.

Learning Objectives

- Discuss the reasoning behind the suggestion that vitamin D deficiency may be a "fundamental risk factor" for reduced work productivity.
- Summarize the newly reported associations between vitamin D status and productivity, including the potential productivity savings for employees at different vitamin D levels.
- Review the study implications for employee health risk assessments and efforts to address risk factors for presenteeism and high health costs.

Employee health status significantly impacts workplace productivity and overall business performance.[1] Increasingly, employers are concerned not only with direct health care costs but also with indirect costs due to employee presenteeism, the state when employees are physically present at work but demonstrate reduced productivity and/or performance due to illness.[2] Presenteeism is financially significant: the cost to employers for presenteeism can exceed even the costs of pharmacy and medical utilization, illness-related absenteeism, or disability.[3] Presenteeism, not absenteeism or disability, accounts for the majority of lost productive time due to both pain conditions[4] and depression.[5] Surprisingly, for 18 common health conditions, presenteeism alone contributes 14% to 73% to total employer health care costs.[3] Presenteeism may cost US employers more than $150 billion per year.[6]

Presenteeism costs are not addressable by employer shifts to higher insurance co-pays and deductibles for both pharmacy and medical costs. The greatest opportunities to reduce presenteeism costs may come from employee health promotion programs such as health risk appraisals (HRAs), disease management programs, and behavior modification programs.[7] From these platforms, targeted investment in reduction of a fundamental risk factor among employees may deliver a powerful return through productivity gains.

Vitamin D deficiency may represent one such fundamental risk factor. Vitamin D deficiency is associated with the numerous conditions that can result in presenteeism,[8] including chronic nonspecific musculoskeletal pain,[9,10] low back pain,[11–13] allergic rhinitis,[14] arthritis,[15–18] asthma,[19–21] cancer,[22–26] depression,[27–30] diabetes,[31,32] gestational diabetes,[33] heart disease,[34,35] hypertension,[36,37] migraine/headache,[38] and respiratory disorders.[39–42] Additional associations related to impaired productivity may include impaired cognition,[43,44] falls,[45] and bone fractures.[46] For many of these conditions, there is an inverse relationship between vitamin D status and either disease activity or functional capacity.

Given these relationships, we hypothesized that vitamin D status may be associated with employee presenteeism. To test this hypothesis, we measured both vitamin D status and workplace productivity (presenteeism) across a large health care system as one part of an annual employee HRA.

METHODS

Participants

As part of an annual Employee Wellness campaign, 20,692 benefits-eligible employees of the Allina Health Care system in Minnesota and western Wisconsin were invited to complete an on-line HRA. Data were collected between January 1 and February 15, 2010. Respondents received $50 in compensation. Employees who completed the supplemental HRA and provided a blood sample to measure their vitamin D level between February 1 and April 1, 2010, were given a $25 gift card.The Allina Hospital and Clinics institutional review board reviewed and approved this protocol prior to any study procedures taking place.

Measures

As part of the HRA, respondents were asked their age, sex, height, weight, race, job classification, vitamin and dietary supplement intake, marital status, and medical history. The HRA also included the validated Workplace Productivity and Activity Impairment (WPAI) Questionnaire[47] that measures work limitations experienced in the prior 7 days as a result of physical or emotional health problems. The WPAI was created and has been used to measure the amount of presenteeism attributable to general health.[47]

All vitamin D measurements were performed at the Allina central laboratory using the LIAISON 25-OH Vitamin D Assay (DiaSorin, Inc, Stillwater, MN), a direct competitive chemiluminescence immunoassay for quantitative determination of total 25-OH

From the Center for Health Care Innovation and Penny George Institute for Health and Healing (Drs Plotnikoff and Dusek), Allina Hospitals and Clinics; and University of Minnesota Carlson School of Management (Dr Finch), Minneapolis, Minn.

Authors Plotnikoff, Finch, and Dusek, received support for this research by the Allina Hospitals and Clinics Employee Benefits Office, the Allina Center for Healthcare Innovation and Diasorin, Inc. Author Plotnikoff has consulted for Diasorin, Inc.

Diasorin Inc. had no role in the design and conduct of the study, the collection, management, analysis, and interpretation of the data, or the preparation or approval of the manuscript.

The JOEM Editorial Board and planners have no financial interest related to this research.

Address correspondence to: Gregory A. Plotnikoff, MD, MTS, Allina Center for Health Care Innovation, Abbott Northwestern Hospital, 800 E. 28th St, Minneapolis, MN 55407. E-mail: gregory.plotnikoff@allina.com.

DOI: 10.1097/JOM.0b013e318240df1e

vitamin D in serum. The coefficient of variability for vitamin D was 12.5% at a level of 15.0 ng/mL and 9.8% at a level of 50.0 ng/mL.

Analysis Procedures

The method for estimating presenteeism from the WPAI has been described previously.[48] In brief, participants were asked, How much do health problems affect productivity while working? On a scale of 0 to 10, participants were instructed to choose a low number if health problems affected their work only a little. Nevertheless, if they determined that their health problems affected their work a great deal, then they were to choose a large number. The participants' presenteeism score is derived when this answer is multiplied by 10 to derive an overall percentage of presenteeism. Each participant's score has a possible range from 0% to 100%. Separate Welch's *t* tests[48] were employed to assess for differences in mean presenteeism by levels of 25-OH vitamin D sufficiency suggested in the current medical literature (>20 ng/mL, >30 ng/mL, and >40 ng/mL).[49,50] Welch's *t* test was employed because of heteroscedasticity.

RESULTS

Of the 20,692 benefits-eligible employees, 14,835 (71.7%) responded to the supplemental HRA. A total of 10,646 employees (51.4%) completed the HRA and provided a blood sample for measurement of 25-OH vitamin D. There were no differences on demographic variables between the group of employees completing just the HRA and the group of participants completing both assessments (Table 1).

The average 25-OH vitamin D level was 28.1 ng/mL (SD = 13.6). Further examination revealed that 6.0% of participants (n = 643) had values lower than 10 ng/mL, 28.9% (n = 2943) were below 20 ng/mL, 60.8% (n = 6198) had values lower than 30 ng/mL, and 83.5% (n = 8512) were lower than 40 ng/mL. A total of 41.3% of participants reported vitamin D supplementation including vitamin D obtained from multivitamins. Of that, 17.8% reported supplementation of more than 1000 IU daily, 6.1% took more than 2000 IU daily, and 2.1% ingested more than 4000 IU every day.

The overall mean presenteeism score for employees was 5.11 (SD = 12.27). The spectrum of presenteeism scores is illustrated by the average presenteeism score for participants with 25-OH vitamin D levels lower than 20 ng/mL of 5.58 (SD = 12.99) and the mean score for those employees with a serum level of 40 ng/mL or higher was 4.48 (SD = 11.24). As shown in Table 2, participants with 25-OH vitamin D levels of 20 ng/mL or higher had significantly lower presenteeism than employees with 25-OH vitamin D levels of lower than 20 ng/mL (P = 0.014). Furthermore, this relationship also was significant for comparisons at vitamin D states of lower than 30 ng/mL and 30 ng/mL or higher (P = 0.0001) as well as lower than 40 ng/mL and 40 ng/mL or higher (P = 0.022).

We also calculated the percentage of payroll (and the dollar amount) lost to presenteeism due to differences in presenteeism for these same groups. These results are shown in the two rightmost columns of Table 2. To illustrate, for the cutoff value of 20 ng/mL, 2943 employees (28.9%) had 25-OH vitamin D levels of lower than 20 ng/mL, and there was a 0.66 absolute difference in presenteeism in the lower than 20 ng/mL group (5.58 to 4.92). Multiplying the absolute difference by the percentage of employees with levels of lower than 20 ng/mL yields the potential percentage of total payroll the employer lost because of differences in presenteeism. For the 20 ng/mL example, this yields a value of 0.19% per employee; for an overall payroll of $1.228 billion for this employer, this difference translates to a potential cost savings of $2.3 million or roughly $112 per employee per year. Significantly, these potential cost savings increase at higher 25-OH vitamin D cutoff values: $326 per employee at a cutoff of 30 ng/mL ($6.8 million) and $370 per employee at 40 ng/mL ($7.7 million). (Fig. 1)

TABLE 1. Sample Characteristics

	Completed HRA Only (n = 14,835)	Completed HRA With Vitamin D Assessment (n = 10,646)
Unknown	0.1	0.5
Some other race	3.1	0.8
Black or African American	4.2	3.3
White	89.4	90.9
Asian or Pacific Islander	1	2.8
American Indian or Alaska Native	0.1	0.5
Chose not to answer	1.7	1.5
Hispanic origin	1.4	1.3
Not of Hispanic origin	89	89.2
Chose not to answer	9.6	9.5
Administrative support	12.5	13.3
Labor or production	2.1	1.9
Professional/management	46.9	45.9
Retired	0	0
Sales	0.1	0.1
Service	7.2	6.9
Skilled craft	2	1.9
Student	0.6	0.4
Technical	13.2	13.9
Other	15.5	15.6
Age, %		
18–39	0.1	0
20–29	16.2	14.9
30–39	23.9	22.7
40–49	25.4	25.7
50–59	26.4	28
60–64	6.2	8.3
≥65	1.8	0.4
Mean age (SD)	43.2 (11.7)	44.3 (11.6)
Female, %	84.7	87.9

DISCUSSION

This study of 10,646 health care employees represents the largest cross-sectional study of employer-based 25-OH vitamin D status and on-the-job productivity to date. The average presenteeism score for our health care employees was just more than 5%, which is comparable to prior reports in which presenteeism ranged from 2% for healthy populations[5,51] to 29% for those with allergies[52] and upward of 40% for individuals with pain.[4]

Importantly, our results suggest that increasing levels of 25-OH vitamin D are associated with significantly improved on-the-job productivity, with the best response at serum 25-OH vitamin D levels greater than 40 ng/mL. This serum level is significantly higher than the level of 20 ng/mL recommended by the Institute of Medicine for bone health.[49] Nevertheless, values greater than 20 ng/mL are consistent with other recommendations for optimal outcomes in the peer-reviewed literature.[50]

The resulting data are economically significant: increasing vitamin D status correlates with increasing on-the-job productivity (reduced presenteeism). For the specific health care employee population studied, the potential employer savings range from a low of 0.19% to a high of 0.63% of total payroll costs depending on the cutoff value of 25-OH vitamin D chosen from 20 ng/mL, 30 ng/mL, or 40 ng/mL (Fig. 2). For this employer, this translates

TABLE 2. Mean Presenteeism and Potential Cost Savings by Threshold Vitamin D Levels

Vitamin D (ng/mL)	*n*	Employees Less Than Cutoff Value, %	Mean Presenteeism Percentage (SD)	Absolute Difference in Presenteeism, %	Potential Payroll Lost, %	Potential Cost Savings Per Employee	Payroll Equivalent
<20	2943	28.9	5.58 (12.99)	0.66*	0.19	$112	$2.33 million
≥20	7256		4.92 (11.96)				
<30	6198	60.8	5.46 (12.93)	0.91**	0.55	$326	$6.78 million
≥30	4001		4.55 (11.15)				
<40	8512	83.5	5.23 (12.46)	0.75*	0.63	$370	$7.68 million
≥40	1687		4.48 (11.24)				

*$P < 0.05$; **$P < 0.001$.

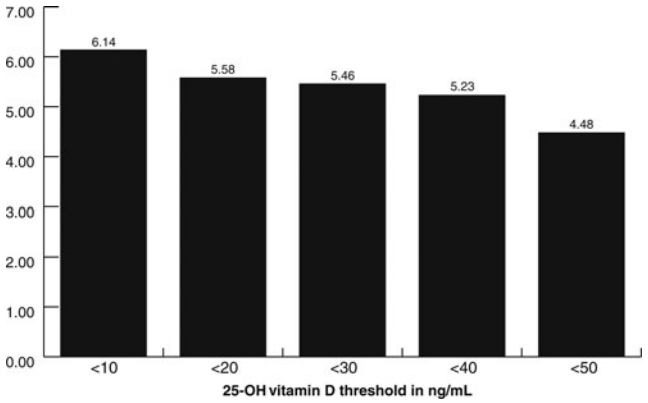

FIGURE 1. Presenteeism by 25-OH vitamin D thresholds.

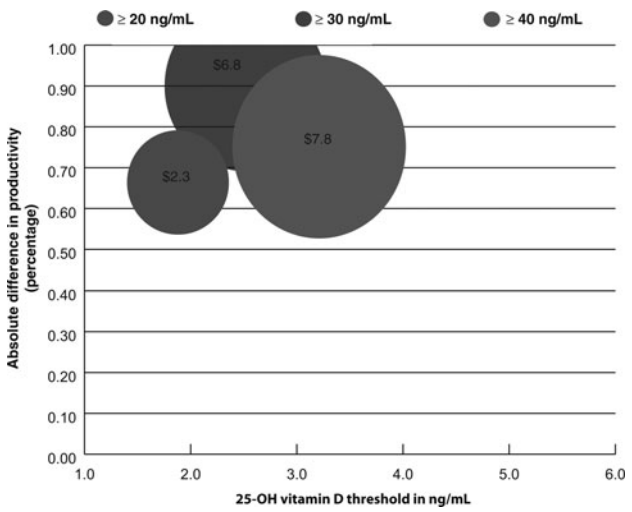

FIGURE 2. Potential payroll savings at study site by achieving suggested levels of vitamin D (in millions).

into potential savings in productivity costs ranging from more than $2.3 million ($112 per employee) to nearly $7.8 million ($370 per employee). For 25-OH vitamin D levels higher than 30 ng/mL, the per employee costs are comparably favorable to 2004 presenteeism cost estimates for the medical conditions with the greatest impact on presenteeism costs including allergy at $271.04, arthritis at $326.88, depression/sadness/mental illness at $348.04, diabetes at $256.91, and migraine/headache at $213.78. These potential savings per employee are significantly better than the estimated presenteeism costs for asthma ($99.55), respiratory tract infections ($133.84), and any cancer ($144.01).[8] This study's findings suggest a significant return on investment for cost-conscious employers given the relative simplicity of 25-OH vitamin D testing and supplementation.

There are several potential limitations to this study. First, employee productivity was measured as presenteeism by the WPAI, a retrospective self-report on the previous week, which may be subject to recall bias. Nevertheless, the WPAI is a widely accepted and validated instrument for measuring productivity.[47] A second limitation is the use of single assessment at one point in time for both the WPAI and vitamin D as the measurement of productivity and vitamin D status throughout the year. With the change of seasons, both health status, such as with allergies and influenza, and vitamin D status may change.[53] Although there is predictive value in snapshots, this limitation highlights the need for long-term prospective studies.

A third limitation may be reduced generalizability to institutions whose employees have vastly different demographic profiles than the current system with employees who are overwhelmingly white and female. These findings may not generalize to different sex and minority status, locations, and/or occupations. Generalizability also may be limited because Minnesota's health care workforce has a relatively high risk of vitamin D deficiency, including wearing ultraviolet B protective lotions, working long hours indoors, and living at a northern latitude where sun exposure for half the year is insufficiently strong to induce vitamin D formation in skin. Nevertheless, the percentages of participants in this study with levels lower than 10 ng/mL, lower than 30 ng/mL, and higher than 30 ng/mL are consistent with National Health and Nutrition Examination Survey data from 2000 to 2004 and, as such, concerns with generalizability may be a nonissue.[54]

Nearly 30% of the health care workers tested had serum 25-OH vitamin D levels lower than the 20 ng/mL recommended by the Institute of Medicine.[49] This surprisingly low vitamin D status needs to be better understood. One potential reason may be the testing in late winter when serum levels are expected to be at their lowest values. We anticipated that health care workers would be more likely to supplement during winter months in Minnesota (>43° north latitude) when solar vitamin D production is not possible. Nevertheless, only 41.3% of participants reported taking any supplemental vitamin D at all, including multivitamins. This low rate is surprising for both the general employee population and the health care professional population. Between 2007 and the start of this study, the general public in Minnesota was exposed to significant radio, television,

and newspaper coverage on vitamin D deficiency as an important public health concern. Minnesota's largest newspaper alone, which reaches 1.6 million metropolitan adults, ran 15 articles about vitamin D during this time including a large front-page Sunday article[55] accompanied by a Web-based video and interactive blog. The results were also surprisingly low for this population of physicians, nurses, and pharmacists given the numerous editorials and commentaries in leading international medical journals since 1998 that have urged physicians to recognize and address vitamin D deficiency in their patients.[56–63] Specific to Minnesota, since 1996, four public health commentaries in *Minnesota Medicine*, the journal of the Minnesota Medical Association, have addressed vitamin D deficiency.[64–67] Significantly, if health care workers, including physicians, nurses, and pharmacists, missed these messages and are vitamin D deficient, then their patients may also be at higher risk for unrecognized deficiency.

These data suggest that an employee vitamin D assessment and replenishment campaign may represent a low-cost, high-return program to mitigate risk factors and health conditions that drive total employer health care costs. The strongly positive employee response to this study demonstrates the practical feasibility of including a vitamin D assessment with an employee HRA and health promotion campaign. Future research should include a prospective intervention to assess the effect of vitamin D status change on presenteeism as well as health care utilization.

ACKNOWLEDGMENTS

The authors thank the many participants including the laboratory personnel and Wellness Champions. The authors also thank Dr Penny Wheeler, Kristyn Mullin, Laura Mahlke, Kay Zemlicka, Tom Mossman, and Shaina Biron for their specific support. They also thank Dr Nico Pronk and HealthPartners for the database creation.

REFERENCES

1. Goetzel RZ, Hawkins K, Ozminkowski RJ, Wang S. The health and productivity cost burden of the "top 10" physical and mental health conditions affecting six large U.S. employers in 1999. *J Occup Environ Med.* 2003;45:5–14.
2. Hemp P. Presenteeism: at work—but out of it. *Harv Bus Rev.* 2004;82:49–58, 155.
3. Schultz AB, Chen CY, Edington DW. The cost and impact of health conditions on presenteeism to employers: a review of the literature. *Pharmacoeconomics.* 2009;27:365–378.
4. Stewart WF, Ricci JA, Chee E, Morganstein D, Lipton R. Lost productive time and cost due to common pain conditions in the US workforce. *JAMA.* 2003;290:2443–2454.
5. Stewart WF, Ricci JA, Chee E, Hahn SR, Morganstein D. Cost of lost productive work time among US workers with depression. *JAMA.* 2003;289:3135–3144.
6. Souberbielle JC, Body JJ, Lappe JM, et al. Vitamin D and musculoskeletal health, cardiovascular disease, autoimmunity, and cancer: recommendations for clinical practice. *Autoimmun Rev.* 2010;9:709–715.
7. Special Committee of Health, Productivity, and Disability Management, American College of Occupational and Environmental Medicine Healthy workforce/healthy economy: the role of health, productivity, and disability management in addressing the nation's health care crisis: why an emphasis on the health of the workforce is vital to the health of the economy. *J Occup Environ Med.* 2009;51:114–119.
8. Goetzel RZ, Long SR, Ozminkowski RJ, Hawkins K, Wang S, Lynch W. Health, absence, disability, and presenteeism cost estimates of certain physical and mental health conditions affecting U.S. employers. *J Occup Environ Med.* 2004;46:398–412.
9. Fabbriciani G, Pirro M, Leli C, et al. Diffuse musculoskeletal pain and proximal myopathy: do not forget hypovitaminosis D. *J Clin Rheumatol.* 2010;16:34–37.
10. Plotnikoff GA, Quigley JM. Prevalence of severe hypovitaminosis D in patients with persistent, nonspecific musculoskeletal pain. *Mayo Clin Proc.* 2003;78:1463–1470.
11. Al Faraj S, Al Mutairi K. Vitamin D deficiency and chronic low back pain in Saudi Arabia. *Spine (Phila Pa 1976).* 2003;28:177–179.
12. Lotfi A, Abdel-Nasser AM, Hamdy A, Omran AA, El-Rehany MA. Hypovitaminosis D in female patients with chronic low back pain. *Clin Rheumatol.* 2007;26:1895–1901.
13. Schwalfenberg G. Improvement of chronic back pain or failed back surgery with vitamin D repletion: a case series. *J Am Board Fam Med.* 2009;22:69–74.
14. Wjst M, Hypponen E. Vitamin D serum levels and allergic rhinitis. *Allergy.* 2007;62:1085–1086.
15. Rossini M, Maddali Bongi S, La Montagna G, et al. Vitamin D deficiency in rheumatoid arthritis: prevalence, determinants and associations with disease activity and disability. *Arthritis Res Ther.* 2010;12:R216.
16. Kerr GS, Sabahi I, Richards JS, et al. Prevalence of vitamin d insufficiency/deficiency in rheumatoid arthritis and associations with disease severity and activity. *J Rheumatol.* 2011;38:53–59.
17. Haque UJ, Bartlett SJ. Relationships among vitamin D, disease activity, pain and disability in rheumatoid arthritis. *Clin Exp Rheumatol.* 2010;28:745–747.
18. Turhanoğlu AD, Güler H, Yönden Z, Aslan F, Mansuroglu A, Ozer C. The relationship between vitamin D and disease activity and functional health status in rheumatoid arthritis. *Rheumatol Int.* 2011;31:911–914.
19. Sandhu MS, Casale TB. The role of vitamin D in asthma. *Ann Allergy Asthma Immunol.* 2010;105:191–199; quiz 200–202, 217.
20. Searing DA, Leung DY. Vitamin D in atopic dermatitis, asthma and allergic diseases. *Immunol Allergy Clin North Am.* 2010;30:397–409.
21. Sutherland ER, Goleva E, Jackson LP, Stevens AD, Leung DY. Vitamin D levels, lung function, and steroid response in adult asthma. *Am J Respir Crit Care Med.* 2010;181:699–704.
22. Otani T, Iwasaki M, Sasazuki S, Inoue M, Tsugane S. Plasma vitamin D and risk of colorectal cancer: the Japan Public Health Center-Based Prospective Study. *Br J Cancer.* 2007;97:446–451.
23. Lappe JM, Travers-Gustafson D, Davies KM, Recker RR, Heaney RP. Vitamin D and calcium supplementation reduces cancer risk: results of a randomized trial. *Am J Clin Nutr.* 2007;85:1586–1591.
24. Giovannucci E, Liu Y, Rimm EB, et al. Prospective study of predictors of vitamin D status and cancer incidence and mortality in men. *J Natl Cancer Inst.* 2006;98:451–459.
25. Amir E, Simmons CE, Freedman OC, et al. A phase 2 trial exploring the effects of high-dose (10,000 IU/day) vitamin D(3) in breast cancer patients with bone metastases. *Cancer.* 2010;116:284–291.
26. Napoli N, Vattikuti S, Ma C, et al. High prevalence of low vitamin D and musculoskeletal complaints in women with breast cancer. *Breast J.* 2010;16:609–616.
27. Milaneschi Y, Shardell M, Corsi AM, et al. Serum 25-hydroxyvitamin D and depressive symptoms in older women and men. *J Clin Endocrinol Metab.* 2010;95:3225–3233.
28. Lee DM, Tajar A, O'Neill TW, et al. Lower vitamin D levels are associated with depression among community-dwelling European men. *J Psychopharmacol.* 2011;25:1320–1328.
29. Jorde R, Sneve M, Figenschau Y, Svartberg J, Waterloo K. Effects of vitamin D supplementation on symptoms of depression in overweight and obese subjects: randomized double blind trial. *J Intern Med.* 2008;264:599–609.
30. Knippenberg S, Bol Y, Damoiseaux J, Hupperts R, Smolders J. Vitamin D status in patients with MS is negatively correlated with depression, but not with fatigue. *Acta Neurol Scand.* 2011;124:171–175.
31. Takiishi T, Gysemans C, Bouillon R, Mathieu C. Vitamin D and diabetes. *Endocrinol Metab Clin North Am.* 2010;39:419–446, table of contents.
32. Kayaniyil S, Vieth R, Retnakaran R, et al. Association of vitamin D with insulin resistance and beta-cell dysfunction in subjects at risk for type 2 diabetes. *Diabetes Care.* 2010;33:1379–1381.
33. Zhang C, Qiu C, Hu FB, et al. Maternal plasma 25-hydroxyvitamin D concentrations and the risk for gestational diabetes mellitus. *PLoS One.* 2008;3:e3753.
34. Lee JH, O'Keefe JH, Bell D, Hensrud DD, Holick MF. Vitamin D deficiency an important, common, and easily treatable cardiovascular risk factor? *J Am Coll Cardiol.* 2008;52:1949–1956.
35. Michos ED, Melamed ML. Vitamin D and cardiovascular disease risk. *Curr Opin Clin Nutr Metab Care*. 2008;11:7–12.
36. Forman JP, Giovannucci E, Holmes MD, et al. Plasma 25-hydroxyvitamin D levels and risk of incident hypertension. *Hypertension*. 2007;49:1063–1069.
37. Anderson JL, May HT, Horne BD, et al. Relation of vitamin D deficiency to cardiovascular risk factors, disease status, and incident events in a general healthcare population. *Am J Cardiol*. 2010;106:963–968.
38. Knutsen KV, Brekke M, Gjelstad S, Lagerlov P. Vitamin D status in patients with musculoskeletal pain, fatigue, and headache: a cross-sectional descriptive study in a multi-ethnic general practice in Norway. *Scand J Prim Health Care*. 2010;28:166–171.

39. Sabetta JR, DePetrillo P, Cipriani RJ, Smardin J, Burns LA, Landry ML. Serum 25-hydroxyvitamin d and the incidence of acute viral respiratory tract infections in healthy adults. *PLoS One*. 2010;5:e11088.
40. Laaksi I, Ruohola JP, Tuohimaa P, et al. An association of serum vitamin D concentrations <40 nmol/L with acute respiratory tract infection in young Finnish men. *Am J Clin Nutr*. 2007;86:714–717.
41. Urashima M, Segawa T, Okazaki M, Kurihara M, Wada Y, Ida H. Randomized trial of vitamin D supplementation to prevent seasonal influenza A in schoolchildren. *Am J Clin Nutr*. 2010;91:1255–1260.
42. Ginde AA, Mansbach JM, Camargo CA Jr. Association between serum 25-hydroxyvitamin D level and upper respiratory tract infection in the Third National Health and Nutrition Examination Survey. *Arch Intern Med*. 2009;169:384–390.
43. Annweiler C, Schott AM, Allali G, et al. Association of vitamin D deficiency with cognitive impairment in older women: cross-sectional study. *Neurology*. 2010;74:27–32.
44. Lee DM, Tajar A, Ulubaev A, et al. Association between 25-hydroxyvitamin D levels and cognitive performance in middle-aged and older European men. *J Neurol Neurosurg Psychiatry*. 2009;80:722–729.
45. Kalyani RR, Stein B, Valiyil R, Manno R, Maynard JW, Crews DC. Vitamin D treatment for the prevention of falls in older adults: systematic review and meta-analysis. *J Am Geriatr Soc*. 2010;58:1299–1310.
46. Bischoff-Ferrari HA, Willett WC, Wong JB, Giovannucci E, Dietrich T, Dawson-Hughes B. Fracture prevention with vitamin D supplementation: a meta-analysis of randomized controlled trials. *JAMA*. 2005;293:2257–2264.
47. Reilly MC, Zbrozek AS, Dukes EM. The validity and reproducibility of a work productivity and activity impairment instrument. *Pharmacoeconomics*. 1993;4:353–365.
48. Welch BL. The generalisation of student's problems when several different population variances are involved. *Biometrika*. 1947;34:28–35.
49. Ross AC, Manson JE, Abrams SA, et al. The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *J Clin Endocrinol Metab*. 2011;96:53–58.
50. Bischoff-Ferrari HA. Optimal serum 25-hydroxyvitamin D levels for multiple health outcomes. *Adv Exp Med Biol*. 2008;624:55–71.
51. Lerner D, Adler DA, Chang H, et al. Unemployment, job retention, and productivity loss among employees with depression. *Psychiatr Serv*. 2004;55:1371–1378.
52. Lamb CE, Ratner PH, Johnson CE, et al. Economic impact of workplace productivity losses due to allergic rhinitis compared with select medical conditions in the United States from an employer perspective. *Curr Med Res Opin*. 2006;22:1203–1210.
53. Barger-Lux MJ, Heaney RP. Effects of above average summer sun exposure on serum 25-hydroxyvitamin D and calcium absorption. *J Clin Endocrinol Metab*. 2002;87:4952–4956.
54. Looker AC, Pfeiffer CM, Lacher DA, Schleicher RL, Picciano MF, Yetley EA. Serum 25-hydroxyvitamin D status of the US population: 1988–1994 compared with 2000–2004. *Am J Clin Nutr*. 2008;88:1519–1527.
55. Marcotty J. Sunday: doctor preaches wonder cure: vitamin D. *Star Tribune*. 2008:A1.
56. Compston JE. Vitamin D deficiency: time for action. Evidence supports routine supplementation for elderly people and others at risk. *BMJ*. 1998;317:1466–1467.
57. Utiger RD. The need for more vitamin D. *N Engl J Med*. 1998;338:828–829.
58. Stokstad E. Nutrition. The vitamin D deficit. *Science*. 2003;302:1886–1888.
59. Meyer C. Scientists probe role of vitamin D: deficiency a significant problem, experts say. *JAMA*. 2004;292:1416–1418.
60. Holick MF. Sunlight and vitamin D: both good for cardiovascular health. *J Gen Intern Med*. 2002;17:733–735.
61. Greer FR. Vitamin D deficiency—it's more than rickets. *J Pediatr*. 2003;143:422–423.
62. Richardson JP. Vitamin D deficiency—the once and present epidemic. *Am Fam Phys*. 2005;71:241–242.
63. Holick MF. High prevalence of vitamin D inadequacy and implications for health. *Mayo Clin Proc*. 2006;81:353–373.
64. Eugster EA, Sane KS, Brown DM. Minnesota rickets. Need for a policy change to support vitamin D supplementation. *Minn Med*. 1996;79:29–32.
65. Plotnikoff GA. Top 10 vitamin D myths. *Minn Med*. 2005;88:38–41.
66. Plotnikoff GA. Vitamin D—the steroid hormone prescription for every patient. *Minn Med*. 2003;86:43–45.
67. Plotnikoff GA. Weather or not: the importance of vitamin D status monitoring and supplementation. *Minn Med*. 2009;92:43–46.

