Vitamin D and Pelvic Floor Disorders in Women

Results From the National Health and Nutrition Examination Survey

Samuel S. Badalian, MD, PhD, and Paula F. Rosenbaum, PhD

OBJECTIVE: To estimate the prevalence of vitamin D deficiency in women with pelvic floor disorders and to evaluate possible associations between vitamin D levels and pelvic floor disorders.

METHODS: Using 2005–2006 National Health and Nutrition Examination Survey data, we performed a cross-sectional analysis of nonpregnant women older than 20 years of age with data on both pelvic floor disorders and vitamin D measurements (n=1,881). Vitamin D levels lower than 30 ng/mL were considered insufficient. The prevalence of demographic factors, pelvic floor disorders, and vitamin D levels were determined, accounting for the multi-stage sampling design; odds ratios (OR) and 95% confidence intervals (CI) were calculated to evaluate associations between vitamin D levels and pelvic floor disorders with control for known risk factors.

RESULTS: One or more pelvic floor disorders were reported by 23% of women. Mean vitamin D levels were significantly lower for women reporting at least one pelvic floor disorder and for those with urinary incontinence, irrespective of age. In adjusted logistic regression models, we observed significantly decreased risks of one or more pelvic floor disorders with increasing vitamin D levels in all women aged 20 or older (OR, 0.94; 95% CI, 0.88–0.99) and in the subset of women 50 years and older (OR, 0.92; 95% CI, 0.85–0.99). Additionally, the likelihood of urinary incontinence was significantly reduced in women 50 and older with vitamin D levels 30 ng/mL or higher (OR, 0.55; 95% CI, 0.34–0.91).

CONCLUSION: Higher vitamin D levels are associated with a decreased risk of pelvic floor disorders in women.
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One in four U.S. women have pelvic floor disorders, including urinary incontinence, pelvic organ prolapse (POP), and fecal incontinence, with increased frequency observed with increasing age. The results were based on responses from a nationally representative sample of 1,961 nonpregnant women aged 20 years and older, included in the 2005–2006 survey.[1] Recently, pelvic floor disorders have been linked to osteoporosis; Pal et al[2] demonstrated a strong relationship between moderate to severe POP and low bone mineral density in postmenopausal women enrolled in the Women's Health Initiative Estrogen Plus Progestin trial. Their findings include an association between clinically significant (defined as moderate to severe) POP, specifically rectocele, and a history of fracture, which suggests that suboptimal collagen status, purported to associate with POP, may also involve bone collagen and hence translate into skeletal compromise.

It is well established that vitamin D deficiency has been associated with numerous health problems including severe osteoporosis.[3,4] Vitamin D insufficiency and deficiency are common in the adult U.S. population, even in those with sufficient exposure to sunlight.[5] Over the past decade, researchers have documented the relationship of vitamin D with functional bone health outcomes (eg, falls, hip fractures, and decreased bone mineral density) in elderly and postmenopausal women.[3,5] In addition, Inderjeeth et al[6] demonstrate a significant association between vitamin D levels and left-leg muscle

From the Department of Obstetrics and Gynecology, SUNY Upstate Medical University, and Gynecology and Urogynecology Center, St. Joseph's Hospital Health Center, Syracuse, New York; Department of Public Health and Preventive Medicine, SUNY Upstate Medical University, Syracuse, New York.

From the National Health and Nutrition Examination Survey data.

Corresponding author: Samuel Badalian, MD, PhD, 104 Union Avenue, Suite #803, Syracuse, NY 13203; e-mail: badalian@netzero.com.

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strength. Because of this independent association, the authors hypothesize that vitamin D deficiency may play a role in poor muscle strength.

Because vitamin D receptors are present in human muscle tissue,[7] a direct effect of vitamin D on muscle physiology is biologically plausible.[8] Thus, it is not surprising that vitamin D deficiency has long been clinically associated with impaired muscle strength[9] and loss of muscle mass.[10] Given that vitamin D insufficiency or deficiency is epidemic among adults,[11–13] it is plausible that low vitamin D status contributes to the development of poor muscle strength and can lead to different pelvic floor disorders such as urinary/fecal incontinence and POP. Crescioli et al[14] and Schröder et al[15] have hypothesized that bladder dysfunction may be related to vitamin D deficiency through effects on the detrusor muscle.

The overall goal of this study was to estimate the prevalence of vitamin D insufficiency or deficiency in women with pelvic floor disorders, and to evaluate possible associations between vitamin D levels and these disorders. To examine these research questions, we estimated the associations of vitamin D levels, POP (vaginal bulge), and female urinary and fecal incontinence using data from the National Health and Nutrition Examination Survey (NHANES) collected during 2005 and 2006. This survey included information on vitamin D intakes and circulating 25-hydroxyvitamin D [25(OH)D] concentrations starting in 1988.

METHODS

The NHANES program began in the early 1960s and has been conducted as a series of surveys focusing on different population groups or health topics. In 1999, the survey became a continuous program focusing on a variety of health and nutrition measurements to meet emerging needs. The survey examines a nationally representative sample of about 5,000 persons each year. These individuals are located in counties across the United States, 15 of which are visited each year. The NHANES detailed in-home interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical and dental examinations, physiologic measurements, and laboratory tests administered by trained medical personnel in a mobile examination center. Trained interviewers obtain written informed consent from each participant for both the in-home interview and the health examination.

The 2005–2006 NHANES oversampled persons aged 60 years or older, as well as African Americans, Mexican Americans, and low-income whites to provide more reliable estimates for these groups. The National Centers for Health Statistics Ethics Review Board approved the protocol, and all participants provided written informed consent. This analysis of NHANES data met criteria for exemption of human subjects research review by the St. Joseph's Hospital Health Center Institutional Review Board.

The 2005–2006 NHANES survey selected 3,440 women aged 20 years or older through probability sampling. Among potential participants, 2,489 women (72.4%) completed the household interview and agreed to participate in the mobile examination center phase of the study.[1] Of these, 2,253 women had data on all three pelvic floor outcomes and 2,337 had vitamin D levels. After eliminating 292 women who were currently pregnant, we were left with 1,961 nonpregnant women with data on pelvic floor disorders and 2,059 with vitamin D measurements. Our final analytic data set comprised 1,881 women with data on both vitamin D levels and pelvic floor disorders.

Participants self-reported their race and ethnicity based on categories that included an open response. In this analysis we used a composite racial/ethnic variable: 1) non-Hispanic white, 2) non-Hispanic African American, 3) Hispanic, and 4) other. Age was assessed in years, with individuals older than 85 years collapsed into one category. Some analyses also were undertaken in which age was grouped as 20 to 49 years and 50 to 85 years or older. Education was categorized as less than high school, high school diploma or general equivalency diploma, some college, or college graduate or higher. Body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, was categorized as less than 25.0, 25.0 to 29.9, 30.0 to 34.9, 35 to 39.9, and 40 and above. Parity (total number of vaginal and cesarean deliveries) was used as a continuous variable in some analyses and categorized as 0, 1, 2, 3, and 4 or more births in others. Definitions for urinary incontinence, fecal incontinence, and POP were identical to those used by the Pelvic Floor Disorders Network in their article describing the prevalence of these disorders in women surveyed in the 2005–2006 NHANES.[1] Specifically, classification of urinary incontinence was based on the responses to frequency and amount of leakage (two NHANES questions) summarized as the "incontinence severity index." Women with a score of 3 or higher were considered to be incontinent, and those with scores lower than 3 were classified as continent. Fecal incontinence was defined as at least monthly leakage of solid, liquid, or mucous stool, also based on responses to a combination of type and frequency of symptom questions. POP was considered positive if individuals answered yes to the question, "Do you experience bulging or something falling out you can see or feel in the vaginal area?" A summary variable of pelvic floor disorders was constructed in which the presence of one or more disorders was coded as 1 and none was coded as 0.

Vitamin D deficiency is defined as a 25(OH)D level less than 10 ng/mL, resulting in rising parathyroid hormone values, impaired mineralization of bone, and an increased risk of fracture and osteomalacia.[16] Vitamin D insufficiency is defined as a 25(OH)D level of 10 to 30 ng/mL.[17] Vitamin D levels between 30 and 80 ng/mL are considered to be in the normal range. We assessed vitamin D as a continuous variable in one set of analyses and as a dichotomous variable in an identical series of analyses, using the "normal range" (at least 30 ng/mL) as one category and values below the normal range (<30 ng/mL) as the reference category, because the mean level for the group was below the normal-range cutoff.

Diasorin's radioimmunoassay (RIA) method was used to measure vitamin D levels. The Diasorin (formerly Incstar; Stillwater, MN) 25(OH)D assay consists of a two-step procedure. The first procedure involves an extraction of 25(OH)D and other hydroxylated metabolites from serum with acetonitrile. After extraction, the treated sample is assayed by using an equilibrium RIA procedure. The RIA method is based on an antibody with specificity to 25(OH)D. The sample, antibody, and tracer are incubated for 90 minutes at 20–25°C. Phase separation is accomplished after 20-minute incubation at 20–25°C with a second antibody-precipitating complex. A non–salt-based buffer is added after this incubation and before centrifugation to aid in reducing nonspecific binding. More detailed information about the Diasorin RIA method can be found on the NHANES Web site (www.cdc.gov/nchs/data/nhanes/nhanes_05_06/vid_d_met_vitamin_d.pdf).

The analysis of NHANES 2005–2006 data was conducted taking into account the complex sampling methodology and sample weights so that proper estimates and standard errors could be calculated. As we included both household interview and mobile examination center data, we used sample weights specific to the latter data as instructed in the Analytic and Reporting Guidelines on the web site. We merged the NHANES 2005–2006 demographic data file with 2005–2006 data concerning reproductive health, bowel health, kidney conditions–urology, body measurements, and vitamin D levels using the unique survey participant identifier, SEQN.

Statistical analyses were conducted using IBM SPSS Complex Samples (SPSS, Chicago, IL). The Complex Samples module incorporates appropriate sample weights and accounts for clustering and stratification used in the NHANES design. The procedures employed in the analysis included CSDESCRIPTIVES, CSTABULATE, CSGLM, and CSLOGISTIC. Parameter estimates and 95% confidence intervals (CIs) were included in all tables. The Rao-Scott adjusted χ^2 test, which accounts for the sampling design[18] effects, was used to assess associations between demographics and age categories, pelvic floor disorders and age categories, and vitamin D categories across both demographics and pelvic floor disorders, individually and as a composite variable. Mean value differences were assessed using the CSGLM procedure and the Wald F. All logistic regression models included odds ratios (OR) and 95% CIs. Logistic regression models were constructed to evaluate associations between vitamin D levels (both as a continuous variable and as a categorical variable) and pelvic floor disorders (one or more versus none) with control for demographic factors shown to be associated with both pelvic floor disorders and vitamin D levels in the literature and in our preliminary analyses. Similarly adjusted models also were constructed to evaluate vitamin D associations and the presence of urinary incontinence, fecal incontinence, and vaginal bulge as defined above. The comparison group in all subtype models was comprised of individuals with negative reports of urinary incontinence, fecal incontinence, or vaginal bulge. Separate models were fitted for all women aged 20 years or older and for women 50 and older for the presence of any pelvic floor disorder and for urinary incontinence. Because of the decreased number of women reporting fecal incontinence and vaginal bulge, models were constructed only for the total group of women aged 20 years or older for these outcomes.

RESULTS

Table 1 shows the weighted prevalence (percentage) and 95% CIs of demographic factors in nonpregnant U.S. women who participated in the NHANES 2005–2006 survey. The mean age (95% CI) of all women was 47.9 (46.4–49.6) years with approximately 72% reporting non-Hispanic white race. The participants were well educated, with more than half reporting at least some college; about 35% had a BMI of 30 or above. Education, race, BMI, and parity all varied (significantly) by age group (20 to 49 years versus 50 to >85 years). Women 50 and older tended to have more children than those who were aged 20 to 49 years and to have had fewer years of schooling. Older women also were

Table 1. Weighted Prevalence and 95% Confidence Intervals of Demographic Factors in Nonpregnant U.S. Women Stratified by Age

Variable	Ages 20 to 49 (n=1,156)	Ages 50 to Older Than 85 (n=1,041)	Ages 20 to Older Than 85 (n=2,197)	Variable* Category
Education†				
Did not complete high school	13.9 (10.6–18.0)	20.4 (17.7–23.5)	16.8 (14.2–19.6)	565
High school diploma or GED	21.6 (19.6–23.7)	29.3 (25.8–33.0)	24.9 (22.7–27.3)	528
Some college	36.0 (32.6–39.5)	27.9 (26.0–29.9)	32.4 (29.9–35.1)	671
College graduate or more	28.5 (23.0–34.8)	22.4 (19.1–26.1)	25.9 (22.1–30.0)	429
Race†				
Hispanic	13.2 (10.5–16.6)	6.4 (4.3–9.5)	10.3 (7.9–13.2)	481
Non-Hispanic white	65.9 (59.2–72.0)	79.1 (72.7–84.3)	71.7 (65.2–77.3)	1,081
Non-Hispanic African American	13.6 (9.6–19.0)	10.4 (6.6–16.0)	12.2 (8.3–17.7)	532
Other	7.3 (4.9–10.7)	4.0 (2.9–5.5)	5.9 (4.3–8.0)	103
BMI (kg/m^2)†				
24.9 and lower	43.3 (38.2–48.6)	33.3 (29.9–36.9)	39.0 (35.4–42.6)	737
25.0–29.9	23.2 (19.4–27.4)	29.0 (25.6–32.7)	25.7 (23.0–28.6)	584
30.0–34.9	15.9 (14.5–17.3)	19.6 (17.1–22.4)	17.5 (16.3–18.7)	422
35.0–39.9	10.9 (8.3–14.2)	9.6 (7.7–12.0)	10.3 (9.0–11.9)	238
40 and higher	6.7 (5.0–9.0)	8.4 (6.8–10.4)	7.5 (6.0–9.2)	172
Parity†				
0	10.4 (7.6–14.0)	3.4 (1.9–6.1)	7.0 (5.1–9.5)	95
1	22.8 (18.8–27.3)	13.3 (10.2–17.2)	18.2 (15.4–21.3)	289
2	33.9 (30.8–37.0)	29.7 (24.7–35.2)	31.8 (28.7–35.1)	474
3	23.0 (20.2–26.1)	22.8 (19.1–26.9)	22.9 (20.3–25.7)	383
4 or more	10.0 (7.3–13.5)	30.8 (24.3–38.1)	20.1 (15.7–25.4)	431

GED, general equivalency diploma; BMI, body mass index.
Data are % (95% confidence interval) or n.
* For the total group of women, ages 20 years and older.
† $P<.001$ from Rao-Scott adjusted χ^2; comparison of each demographic variable across age groups.

more likely to report being non-Hispanic white than women between 20 and 49 years of age.

Table 2 summarizes 25(OH)D levels and the frequency of pelvic floor disorders across age groups and for the entire sample. About 82% of women had 25(OH)D levels lower than 30 ng/mL with an overall mean (95% CI) level of 21.6 (20.4–22.7) ng/mL. Pelvic floor disorders increased with age; 14% of women younger than 50 years of age reported one or more pelvic floor disorders, while the prevalence was 34% among those 50 and older. Older women also were significantly more likely to have 25(OH)D levels lower than 30 ng/mL than younger women. The mean 25(OH)D values for the two age groups were not statistically different (21.9 versus 21.1 ng/mL); however, the mean for the entire group was below the current lower limit for 25(OH)D sufficiency of 30 ng/mL.[8]

Table 3 shows the weighted prevalence of demographic factors within categories of 25(OH)D levels (below normal versus normal range). Women with less than a high school education were more likely to be in the lower 25(OH)D category than those with at least some college. Among the racial groups, non-Hispanic whites were more frequent in the higher vitamin D category relative to non-Hispanic African Americans and Hispanics. BMI showed an inverse association with 25(OH)D; those with higher BMI had lower 25(OH)D levels. We observed similar patterns for women 50 years of age and older across the demographic variables.

The weighted prevalence of each type of pelvic floor disorder across 25(OH)D categories in all women, and for women at least 50 years of age also appears in Table 3. The prevalence of urinary incontinence and one or more pelvic floor disorders was significantly higher in individuals with 25(OH)D levels below the normal range as compared to those with levels at 30 ng/mL or higher. The pattern was similar for fecal incontinence, but not significant. Contrary to expectation, vaginal bulge was more frequent in older women with higher 25(OH)D levels.

We performed multivariable logistic regression analysis using the data for women 20 years or older to evaluate the effect of 25(OH)D on the presence or absence of at least one pelvic floor disorder while controlling for age, race, education, BMI, and parity (see Table 4). In the overall model assessing the association between continuous 25(OH)D levels and

Table 2. Weighted Prevalence and 95% Confidence Intervals of Vitamin D Levels and Pelvic Floor Disorders in Nonpregnant U.S. Women Stratified by Age

Variable	Ages 20 to 49 (n=1,156)	Ages 50 to Older Than 85 (n=1,041)	Ages 20 to Older Than 85 (n=2,197)	Variable* Category
Vitamin D levels (ng/mL)†				
Less than 30	80.1 (74.6–84.6)	85.0 (81.1–88.1)	82.2 (78.1–85.7)	1,794
30 or more	19.9 (15.4–25.4)	15.0 (11.9–18.9)	17.8 (14.3–21.9)	265
Mean level	21.9 (20.4–23.4)	21.1 (20.0–22.2)	21.6 (20.4–22.7)	2,059
Pelvic floor disorders				
Urinary incontinence‡				
No	90.7 (88.4–92.6)	76.0 (72.6–79.2)	84.3 (81.7–86.6)	1,619
Yes	9.3 (7.4–11.6)	24.0 (20.8–27.4)	15.7 (13.4–18.3)	331
Fecal incontinence‡				
Never	94.9 (92.9–96.4)	86.0 (83.6–88.1)	91.0 (89.2–92.6)	1,762
Yes (at least monthly)	5.1 (3.6–7.1)	14.0 (11.9–16.4)	9.0 (7.4–10.8)	176
Bulge in vagina‡				
No	98.1 (97.1–98.7)	95.8 (93.8–97.2)	97.1 (96.2–97.8)	1,835
Yes	1.9 (1.3–2.9)	4.2 (2.8–6.2)	2.9 (2.2–3.8)	58
Number of pelvic floor disorders‡				
0	85.8 (82.8–88.3)	65.8 (62.4–69.0)	77.0 (74.0–79.8)	1,491
1	12.3 (10.0–15.2)	27.9 (25.1–30.9)	19.2 (16.8–21.7)	386
2	1.7 (1.2–2.6)	5.4 (4.0–7.4)	3.4 (2.5–4.5)	73
3	0.2 (0.0–0.6)	0.9 (0.4–2.2)	0.5 (0.2–1.1)	11
Any pelvic floor disorder†				
None	85.8 (82.8–88.3)	65.8 (62.4–69.0)	77.0 (74.0–79.8)	1,491
1 or more	14.2 (11.7–17.2)	34.2 (31.0–37.6)	23.0 (20.2–26.0)	470

Data are % (95% confidence interval) or n.
* For the total group of women, ages 20 and above.
† P=.03 from Rao-Scott adjusted χ^2; comparison of categorical vitamin D variable by age groups. No difference in means.
‡ P<.001 from Rao-Scott adjusted χ^2; comparison of each pelvic floor disorder variable across age groups.

any pelvic floor disorder, the adjusted OR and 95% CI were 0.94 (0.88–0.99), indicating a 6% significant decrease in the risk of pelvic floor disorders with each 5-ng/mL increase in 25(OH)D levels (P=.043). Both increasing age and BMI significantly predicted the presence of pelvic floor disorders in this model whereas parity and education did not; the probability value for race was .06, with non-Hispanic African-American women having a lower risk compared with non-Hispanic whites (data not shown). Results were similar when restricting the analysis to women 50 and older; the adjusted OR (95% CI) for 25(OH)D was 0.92 (0.85–0.99), P=.039, indicating a significant 8% decrease in the risk of pelvic floor disorders with each 5-ng/mL increase in 25(OH)D.

Similar models were fitted using the categorical version of 25(OH)D (below normal values versus normal range values) and the presence of one or more pelvic floor disorders. As shown in Table 4, women with 25(OH)D levels in the normal range (at least 30 ng/mL) had a nonsignificant decreased risk of pelvic floor disorders compared with women with levels below 30 ng/mL; the adjusted OR (95 CI) was 0.75 (0.54–1.04), P=.084. Results from analyses of the categorical variable in older women were similar, also showing a nonsignificant decreased risk of one or more pelvic floor disorders with higher vitamin D levels.

Using urinary incontinence as the outcome in the multivariable logistic regression model (Table 4) rather than all pelvic floor disorders, we found a nonsignificant decrease in the risk of urinary incontinence with each 5-ng/mL increase in the continuous vitamin D in all women and in those 50 years and older. Similarly, in the categorical vitamin D analyses in all women 20 years of age and older, we noted a nonsignificant decreased risk of urinary incontinence with 25(OH)D levels of at least 30 ng/mL (normal range) compared with those whose levels were below 30 ng/mL. In these models, increasing BMI and age also were significantly associated with an increased risk of urinary incontinence, while parity, education, and race were of borderline significance (.05<P<.10). The vitamin D–urinary incontinence association was stronger in older women; the odds ratio (95% CI) was 0.55 (0.34–0.91), P=.022, indicating a 45% reduction in risk of urinary incontinence with vitamin D levels in the normal range.

As shown in Table 5, the multivariable modeling results using fecal incontinence as the dependent vari-

Table 3. Weighted Prevalence and 95% Confidence Intervals of Demographic Factors and Pelvic Floor Disorders by Vitamin D Levels in Nonpregnant U.S. Women Older than 19 Years

	Vitamin D Levels for Women Aged 50 Years or Older		Vitamin D Levels for Women Aged 20 Years or Older	
Variable	Less Than 30 ng/mL	30 ng/mL or More	Less Than 30 ng/mL	30 ng/mL or More
Education*				
Did not complete high school	21.4 (18.2–25.1)	10.6 (4.8–21.9)	18.3 (15.4–21.4)	7.7 (4.6–12.7)
High school diploma or GED	29.1 (25.2–33.3)	30.9 (21.8–41.8)	25.3 (22.6–28.3)	21.7 (16.7–27.8)
Some college	28.6 (26.3–31.0)	28.5 (21.3–37.0)	31.8 (29.1–34.6)	38.4 (33.2–43.8)
College graduate or more	20.9 (17.4–25.0)	29.9 (19.7–42.7)	24.6 (20.7–28.9)	32.2 (26.2–38.8)
Race*†				
Hispanic	7.3 (5.0–10.5)	1.8 (0.6–5.6)	11.8 (9.2–15.0)	3.3 (2.3–4.8)
Non-Hispanic white	77.0 (70.3–82.6)	94.3 (89.4–97.0)	68.1 (61.2–74.3)	91.7 (87.0–94.8)
Non-Hispanic African American	11.3 (7.3–17.1)	2.7 (1.1–6.6)	14.0 (9.4–20.4)	1.4 (0.6–3.3)
Other	4.4 (3.1–6.2)	1.2 (0.2–7.3)	6.1 (4.5–8.2)	3.5 (1.3–9.5)
BMI (kg/m^2)*†				
24.9 or higher	28.9 (25.2–33.0)	55.5 (46.4–64.3)	34.2 (30.8–37.7)	60.6 (53.4–67.3)
25.0–29.9	29.4 (25.8–33.4)	27.3 (19.1–37.4)	26.1 (23.6–28.8)	22.7 (16.3–30.7)
30.0–34.9	21.0 (17.8–24.8)	10.2 (6.3–16.1)	18.9 (17.6–20.3)	10.8 (7.5–15.3)
35.0–39.9	11.1 (8.8–13.9)	2.6 (0.7–9.1)	12.1 (10.3–14.2)	3.8 (2.0–7.1)
40 or more	9.5 (7.7–11.7)	4.3 (2.0–9.2)	8.7 (7.0–10.8)	2.1 (1.6–2.8)
Urinary incontinence*†				
No	74.3 (70.9–77.3)	86.0 (79.0–90.9)	82.8 (80.0–85.2)	90.2 (86.9–92.7)
Yes	25.7 (22.7–29.1)	14.0 (9.1–21.0)	17.2 (14.8–20.0)	9.8 (7.3–13.1)
Fecal incontinence				
Never	85.5 (82.6–88.0)	87.5 (80.8–92.1)	90.2 (88.0–92.0)	93.8 (89.5–96.4)
Yes (at least monthly)	14.5 (12.0–17.4)	12.5 (7.9–19.2)	9.8 (8.0–12.0)	6.2 (3.6–10.5)
Bulge in vagina†				
No	96.7 (94.9–97.8)	91.4 (81.1–96.3)	97.2 (96.5–97.8)	96.3 (92.6–98.2)
Yes	3.3 (2.2–5.1)	8.6 (3.7–18.9)	2.8 (2.2–3.5)	3.7 (1.8–7.4)
Any pelvic floor disorder*†				
None	64.5 (60.8–68.0)	72.1 (65.4–77.8)	75.2 (71.7–78.3)	83.3 (79.3–86.7)
1 or more	35.5 (32.0–39.2)	27.9 (22.2–34.6)	24.8 (21.7–28.3)	16.7 (13.3–20.7)

GED, general equivalency diploma; BMI, body mass index.
Data are % (95% confidence interval).
P values from a Rao-Scott adjusted χ^2.
* $P \leq .05$ in comparison of demographics/disorders across vitamin D levels in all women aged 20 years and older.
† $P \leq .05$ in comparison of demographics/disorders across vitamin D levels in women aged 50 years and older.

able were similar to those for pelvic floor disorders and urinary incontinence in terms of the magnitude of the odds ratio and the direction of the effect; however, the confidence intervals included the null value and were consistent with no association for both the continuous and the categorical vitamin D assessments.

Results from multivariable modeling of vaginal bulge (Table 5) also were consistent with the null effect; however, the odds ratios were above 1.0, consistent with an increase in risk of vaginal bulge with higher vitamin D levels.

DISCUSSION

Results from our study indicated that approximately 82% of nonpregnant women 20 years of age and older from the NHANES 2005–2006 survey had 25(OH)D levels below the lower cutoff for the normal range (<30 ng/mL). Consistent with our hypothesis, higher vitamin D levels were associated with a decreased risk of any pelvic floor disorder in all women ($P=.043$) and in women 50 years and older ($P=.039$). In older women, we also observed a decrease in the risk of urinary incontinence if 25(OH)D levels were within the normal range (at least 30 ng/mL, $P=.022$); these associations remained significant after controlling for age, BMI, race, education, and parity, factors showing significant associations with pelvic floor disorders in previous studies.[1]

Although there was a decreased risk of fecal incontinence with increasing vitamin D levels, the association was not significant. This may be secondary to the small number of cases in this subset of pelvic floor disorders and reduced power (post hoc power was 63%). Some women with fecal incontinence may deny symptoms, resulting in underreporting of this disorder.

Table 4. Multivariable Logistic Regression Models Summarizing the Association Between Vitamin D Levels and Pelvic Floor Disorders and Urinary Incontinence in Nonpregnant U.S. Women

Dependent Variable	Women Aged 20 Years or Older	*P*	Women Aged 50 Years or Older	*P*
Pelvic floor disorders				
Model A1: vitamin D (ng/mL) per 5-unit increase	0.94 (0.88–0.99)	.043		
Model A2: vitamin D levels (ng/mL)				
Less than 30	1.00 (Reference)	.084		
30 or more	0.75 (0.54–1.04)			
Model A3: vitamin D (ng/mL) per 5-unit increase			0.92 (0.85–0.99)	.039
Model A4: vitamin D levels (ng/mL)				
Less than 30			1.00 (Reference)	.187
30 or more			0.79 (0.56–1.14)	
Urinary incontinence				
Model B1: vitamin D (ng/mL) per 5-unit increase	0.94 (0.85–1.04)	.188		
Model B2: vitamin D levels (ng/mL)				
Less than 30	1.00 (Reference)	.098		
30 or more	0.70 (0.45–1.08)			
Model B3: vitamin D (ng/mL) per 5-unit increase			0.92 (0.81–1.03)	.125
Model B4: vitamin D levels (ng/mL)				
Less than 30			1.00 (Reference)	.022
30 or more			0.55 (0.34–0.91)	

Data are adjusted odds ratio (95% confidence interval) unless otherwise specified.
Other covariables in all models include age in years, body mass index (five categories), parity (continuous), education (four categories), and race or ethnicity (four categories).

Although a bulge in the vagina was reported infrequently, significantly more women older than 50 years of age had this complaint compared with those between 20 and 49. In older women, those with reports of a vaginal bulge also were significantly more likely to have vitamin D levels in the normal range, a finding contrary to expectation and in need of further study. The total number of women older than 50 years reporting vaginal bulge in the study was 35, the majority of whom (86%) were non-Hispanic white women. This racial group had significantly higher mean vitamin D levels than each of the other racial groups (data not shown). Moreover, as vaginal bulge was self-reported in the NHANES study population, the prevalence of POP was likely underreported. Consequently, these factors may have impacted our point estimates of the association of vitamin D levels with this outcome. Nonetheless, POP remains one of the most common reasons for gynecologic surgery among women. The failure rate is estimated at 30%, and requires a second operation.[19] Despite the high prevalence of POP, little is known about the underlying pathophysiology and contributing risk factors.

The development of pelvic floor disorders is multifactorial; multiparity, older age, overweight, chronic straining, and obstructive lung diseases have been shown to be important risk factors in some studies.[20,21] Patients with higher parity tend to develop POP more frequently, with aging and menopause as superimposed decompensation factors.[22] Nulliparous women also have been observed to develop POP; consequently, a genetic predisposition and environmental or nutritional factors are thought to play a role in POP development as well.[22–24] As in other studies, our models found that increasing age and higher BMI were significantly associated with any pelvic floor disorder, and with each of the individual disorders in the NHANES study population. Increasing parity was associated primarily with an increased risk of urinary incontinence in this population but was not a significant predictor of fecal incontinence or any pelvic floor disorder overall.

It has been hypothesized that bladder dysfunction may be related to vitamin D deficiency. Urinary continence requires coordinated muscle function with relaxation of the detrusor muscle allowing the bladder to fill, followed by detrusor contraction with concomitant sphincter relaxation under voluntary control by the individual.[14,15] Despite the plausible association of low 25(OH)D status with bladder dysfunction, only a single study has investigated this relationship in a longitudinal study, in which 5,816 community-dwelling women older than 40 years of age completed a postal survey.[25] The authors found that a higher dietary vitamin D intake was associated ($P<.01$) with lower risk of the onset of overactive bladder and

Table 5. Multivariable Logistic Regression Models Summarizing the Association of Vitamin D Levels With Fecal Incontinence and Vaginal Bulge in Nonpregnant U.S. Women

Dependent Variable	Women Aged 20 Years or Older	P
Fecal incontinence		
Model A1: vitamin D (ng/mL) per-5 unit increase	0.93 (0.83–1.04)	.183
Model A2: vitamin D levels (ng/mL)		
Less than 30	1.00 (Reference)	.163
30 or more	0.66 (0.36–1.21)	
Vaginal bulge		
Model B1: vitamin D (ng/mL) per 5-unit increase	1.03 (0.90–1.18)	.632
Model B2: Vitamin D levels (ng/mL)		
Less than 30	1.00 (Reference)	.298
30 or more	1.66 (0.61–4.49)	

Data are adjusted odds ratio (95% confidence interval) unless otherwise specified.
Other covariables in all models include age in years, body mass index (five categories), parity (continuous), education (four categories), and race or ethnicity (four categories).

concluded that the potential role of vitamin D in detrusor muscle functioning needs to be considered. Our findings of an effect of vitamin D levels on urinary incontinence are supportive of the findings of Dallosso and colleagues.[25]

Our study has some limitations that should be considered when interpreting these findings. The National Center for Health Statistics states that 25(OH)D data from the 2000–2006 NHANES may be affected by drifts in the assay performance (method bias and imprecision) over time, making comparisons of vitamin D levels between multiple NHANES surveys difficult. Our analysis was restricted to one survey period, 2005–2006, which attenuated the vitamin D drift issue but limited our power to see subtype and smaller effect sizes such as those observed for fecal incontinence.

Second, it is difficult to perform population-based epidemiologic studies of pelvic floor disorders, particularly POP, because a gynecologic examination is required to assess the severity of pelvic organ prolapse. We avoided this limitation by screening for prolapse based on the presence of one or more prolapse-related symptoms following the method used by Nygaard et al.[1] In their recent analysis of NHANES data, they noted that studies using symptom-based screening likely underestimate the true prevalence of anatomic disease but remain the most accurate measure of disease burden in a general population survey.

In summary, higher vitamin D levels were associated with a decreased risk of any pelvic floor disorder in women 20 years and older, and among those who were 50 or older. The vitamin D association was strongest among older women reporting urinary incontinence in the NHANES survey. The pattern was similar for fecal incontinence although not significant. Vaginal bulge was reported more frequently among those with higher vitamin D levels, a finding contrary to expectation. Given the increase in the number of patients with pelvic floor disorders, further evaluation of the role of vitamin D is warranted, particularly future research to assess the relationship between vitamin D levels and pelvic muscle strength in women of all ages and racial/ethnic groups. Our findings suggest that treatment of vitamin D insufficiency and deficiency in both premenopausal and postmenopausal women could improve pelvic muscle strength, with a possible reduction in the prevalence of pelvic floor disorders including urinary incontinence.

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