Development of a Noninvasive Vitamin D Screening Tool

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The purpose was to develop a vitamin D screening tool for use in community health/wellness settings. Fifty-four healthy Caucasian women of normal weight (body mass index = 18–24.9) and obese weight (body mass index ≥30) had anthropometrics measured, and completed three-day food records, vitamin D screening tools, and serum 25-hydroxyvitamin D tests. Findings provided evidence of usefulness of three specific screening tool items (sunscreen use, obesity, dairy consumption) and indicated need for more precision about sunscreen use. Odds for vitamin D inadequacy were 5 times lower with sunscreen use, 6 times higher with low dairy consumption, and 10 times higher with self-reported obesity, X^2 (5, n = 54) = 43.24, P <.01. The study provided initial verification of self-report items useful in assessing vitamin D inadequacy. Following refinement and testing with larger, less homogeneous samples, the instrument can serve as a useful, cost-effective vitamin D screening tool in community health/wellness settings.

Keywords: *vitamin D; screening tool; obesity; sunscreen use; dairy consumption*

Vitamin D insufficiency is increasing across all age groups (Looker et al., 2008). Recent research implicates vitamin D insufficiency as a risk factor for a variety of chronic diseases including type 1 and 2 diabetes, osteoporosis, cardiovascular disease, hypertension, metabolic syndrome, and cancer (Heaney, 2008; Holick, 2006). Sufficient serum levels of vitamin D also are important for maintaining bone strength in children and adults. Because vitamin D plays a key role in maintaining bone health, the Institute of Medicine (IOM) recently increased the recommended daily allowance (RDA) for vitamin D from 200 to 600 IU for individuals aged 1–70 years (IOM, 2011).

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Researchers have observed inverse relationships between serum 25-hydroxy-vitamin D (25[OH]D) and both body mass index (BMI) and fat mass (Gagnon, Baillargeon, Desmarais, & Fink, 2010; Parikh et al., 2004; Wortsman, Matsuoka, Chen, Lu, & Holick, 2000). This is important because obesity rates have doubled within the United States over the last two decades, and 68% of the United States (U.S.) population over 20 years of age are overweight or obese (Center for Disease Control (CDC), 2010. Obese individuals require greater vitamin D_3 supplementation to raise serum 25(OH)D levels (Arunabh, Pollack, Yeh, & Aloia, 2003), and exposure of obese individuals to irradiation is less effective for vitamin D synthesis, likely due to a sequestering of vitamin D in adipose tissue (Wortsman et al., 2000).

Vitamin D inadequacy persists despite the fortification of common foods (Holick, 2006; O'Donnell et al., 2008). Exposure of skin to sun is the only reliable mechanism for the body to synthesize its own vitamin D (Holick et al., 1980); however, to reduce the risk of melanoma, many apply sunscreen prior to sun exposure, which blocks up to 99% of vitamin D biosynthesis (Gilchrest, 2008; Sayre & Dowdy, 2007). Furthermore, in northern latitudes (north of 37 degrees), insufficient vitamin D is produced by the skin during winter months even when sunscreen is not used (Holick, 2006).

Assessment of serum 25(OH)D requires a blood test, a procedure not routinely ordered by healthcare providers. Vitamin D status is declining (Looker et al., 2008), so it is important that testing be implemented when appropriate. A non-invasive screening tool could help determine the need for serum 25(OH)D testing, but currently, no validated, reliable, multi-item vitamin D screening tool exists that is intended for self-administration in community health/wellness settings. The purpose of this study was to begin development of such an instrument to assess risk for vitamin D inadequacy. To this end, serum 25(OH)D was used as the biomarker for vitamin D status, and the relationship of survey items with the biomarker validated the survey items in disparate body-weight groups.

REVIEW OF THE LITERATURE

Researchers have found that vitamin D status in the U.S. population has declined over the past two decades, partly attributable to changes in BMI, protection from the sun, and consumption of milk (Looker et al., 2008). Positive relationships repeatedly have been established between vitamin D inadequacy and each of the following: obesity (Parikh et al., 2004; Wortsman et al., 2000), protection of the skin from the effects of the sun (Sayre & Dowdy, 2007), and consumption of fewer dairy products (O'Donnell et al., 2008). As vitamin D insufficiency has been associated with a number of serious diseases (Heaney, 2008), it is important that vitamin D status be monitored in Americans, a population that has grown heavier (CDC, 2010; Flegal, Carroll, Ogden, & Curtin, 2010; Looker et al., 2008), consumes inadequate amounts of vitamin D from food (Looker et al., 2008; Moshfegh, Goldman, & Cleveland, 2005), and is more likely than past generations to use sunscreen to protect themselves from sun damage and melanoma (Looker et al., 2008).

Screening Tools

No multi-item Vitamin D screening tool was found in the literature, although self-reporting of exposure to the sun has been tested. One study found

correlations between serum 25(OH)D levels and questionnaire data assessing recall of past sun exposure (van der Mei, Blizzard, Ponsonby, & Dwyer, 2006). While this finding is supportive of the use of self-report in assessing vitamin D levels, the fact remains that sun exposure represents only one factor contributing to serum 25(OH)D concentrations (Arunabh et al., 2003; Gagnon et al., 2010; O'Donnell et al., 2008; Wortsman et al., 2000). McCarty (2008), in a review of the usefulness of self-reporting of sun exposure, concluded that such measures correlated poorly with serum 25(OH)D, and questionnaires assessing only self-reported sun exposure represented inadequate proxies for vitamin D status. The following review reflects findings about the five specific variables (obesity, sunscreen use, dairy consumption, medicine intake, and fall–winter depression) tested in this pilot study of Caucasian women.

Obesity

Consistently, obese individuals have been assessed with vitamin D insufficiency (Gagnon et al., 2010; Parikh et al., 2004; Wortsman et al., 2000). While obesity does not restrict the production of vitamin D_3 by the skin, 24 hr following exposure to irradiation, obese individuals have been found to have much lower concentrations of serum 25(OH)D than identically exposed lean individuals (Wortsman et al., 2000). It is likely that because vitamin D is fat soluble, there may have been a sequestering of vitamin D_3 in the subcutaneous fat, which is more abundant in obese individuals (Wortsman et al., 2000).

While it has been established that obesity is negatively related to vitamin D status, it is typical for women to underreport their correct weight (Engstrom, Paterson, Doherty, Trabulsi, & Speer, 2003; Ezzati, Martin, Skjold, Hoorn, & Murray, 2006; Villanueva, 2001). This presents a concern for the use of a tool that requires self-reporting of obesity. Villanueva (2001), for example, reported that women with BMIs indicating obesity were 66%–87% more likely to underestimate their correct weight. In a review of studies of self-reported height and weight, Engstrom et al. (2003) found that in 21 of 26 studies, women overestimated height, and in 34 of 34 studies, women underestimated weight. Ezzati et al. (2006) reported similar findings. Such inaccuracies in self-reported height and weight values make accurate calculation of BMIs unlikely. Whether self-reporting of *obesity* by women is accurate, however, is not clear. While it is important to measure height and weight rather than relying on self-reported data when computing BMIs to determine obesity, actual measurement in community settings may not be feasible or appropriate. One goal in developing the screening tool was to determine whether self-reporting of obesity would provide an acceptable level of accuracy to serve as a proxy for BMI computed from measurements.

Sunscreen Use

The only reliable method of vitamin D synthesis by the body is exposure to sunlight (Holick et al., 1980). Overexposure to ultraviolet radiation from sunlight poses risks for melanoma, however, (Gilchrest, 2008), so the recommended practice is year-round, routine use of sunscreen (American Academy of Dermatology, 2011). Many Americans follow this practice, which makes the photochemical formation of previtamin D_3 ineffective (Looker et al., 2008;

Sayre & Dowdy, 2007). One of the important indicators that needs testing in a tool screening for the risk of vitamin D inadequacy, then, is the routine use of sunscreen.

Dairy Consumption

Another variable related to vitamin D status is consumption of foods containing vitamin D (Moshfegh et al., 2005; O'Donnell et al., 2008; National Institutes of Health, Office of Dietary Supplements (NIH-ODS), 2011. While vitamin D does occur naturally in a few foods (e.g., fatty fish, egg yolks, fish liver oils; NIH-ODS, 2011), Americans typically do not consume enough such foods to provide adequate intake of vitamin D (Moshfegh et al., 2005). Vitamin D fortification of foods in the American diet was recognized as an inexpensive solution, and vitamin D-fortified foods have been widely available for over half a century (O'Donnell et al., 2008).

In a systematic review of studies reporting the effects of foods fortified with vitamin D on serum 25(OH)D concentrations, O'Donnell et al. (2008) indicated that vitamin D status improved with intake of such foods. An important source of vitamin D-fortified foods in the United States is the family of dairy products, including such foods as milk, yogurt and cheese (NIH-ODS, 2011; O'Donnell et al., 2008). An item to measure the consumption of dairy products, then, was essential for inclusion on a screening tool designed to assess the risk for vitamin D inadequacy. Consumption of fewer than three servings per day was chosen as the indicator, as the recommended number of servings is at least 3/day (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). No other types of fortified foods were included, because fortification across other categories of foods is neither uniform nor universal. Additionally, individuals in the population may not know whether other types of foods they consume, such as orange juice, have been fortified.

Vitamin D Supplementation

The U.S. Department of Health and Human Services recommends that dietary supplementation of vitamin D should be assessed in nutrient intake studies because vitamin D occurs naturally in very few foods (Gahche et al., 2011). If supplement use is ignored, then estimates of vitamin D intake may be greatly underestimated. Most recent National Health and Nutrition Examination Surveys (NHANES) data indicate that vitamin D intake through supplements has not changed for women aged 20–39 years from 1988–1994 through 2003–2006. Vitamin D supplementation rates increased from 1988–1994 through 1999–2002 for women aged 40–59 years, but remained unchanged for 2003–2006 (Gahche et al., 2011).

Medication Use

Specific medications have been found to alter vitamin D status. Oral contraceptives, for example, are associated with increased serum 25(OH)D concentrations (Gagnon et al., 2010). Drugs such as anticonvulsants and glucocorticoids have been found to lower serum 25(OH)D concentrations (NIH-ODS, 2011). It

was important to determine whether assessment of the use of such medications was a relevant indicator for inclusion on the screening tool.

Fall–Winter Depression

There has been some evidence of a relationship between vitamin D and the presence of depressed mood during the fall and winter seasons. Mood in subjects with seasonal affective disorder (SAD) improved significantly after treatment with vitamin D (Gloth, Alam, & Hollis, 1999; Lansdowne & Provost, 1998; Vieth, Kimball, Hu, & Walfish, 2004). While evidence for the relationship between vitamin D status and fall–winter depression exists, Bertone-Johnson (2009) contends that the topic merits further study. For this reason, a fall–winter depression item has been included on the screening tool.

METHODOLOGY

Subjects

The study, conducted March–May 2010, was exploratory and cross-sectional in design. The Institutional Review Board at Northern Illinois University granted approval for the study. Recruitment flyers were posted university-wide and in nearby fitness centers, and applicants were screened for eligibility. Exclusion criteria included men, age range <18 and >50, race other than Caucasian, BMI values <18 and 25–29.9, pregnancy, hemophilia, hepatic or renal disease, and vitamin D supplementation >1,500 IU/day. A power analysis was conducted; inclusion of 27 subjects/group (normal weight and obese) provided 80% power for detecting an effect size of $f = .39$ at $p = .05$ with respect to differences in serum 25(OH)D levels using an analysis of covariance ANCOVA (Cohen, 1988). Two of the 56 applicants were screened out; three subjects declined to participate and were replaced with three new recruits. Participants were not compensated beyond the free serum 25(OH)D tests and diet analyses.

Participants signed consent forms, then submitted 3-day food records, completed vitamin D status screening tools, and had anthropometric measurements assessed. Subjects' 3-day food records were examined by the primary investigator (a registered dietitian with a PhD) for completeness; missing portion sizes were clarified to eliminate missing data. Participants who reported consuming orange juice were queried as to whether they knew if it was vitamin D-fortified, and vitamin D supplementation intake (assessed during screening) was verified again. Food records later were analyzed by a graduate-level nutrition student using Diet Analysis+ for Windows Version 8 (Stamford, CT). On a separate day, subjects reported to a Laboratory Corporation of America (LCA) site for serum 25(OH)D testing.

Measurement

Anthropometrics. Anthropometric measurements were assessed by the primary investigator with subjects in lightweight clothing, bare feet and having fasted from food or caffeinated beverages. To assure adequate hydration,

subjects consumed 16 oz water (2 hr prior), refrained from exercise, and emptied their bladders before body composition analysis. A bioelectrical impedance scale (InBody 520; Biospace Inc., Los Angeles, CA) assessed weight, and a wall-mounted stadiometer (S-100 Ayrton Corp., Prior Lake, MN) measured height. For each participant, height was measured twice, then averaged, and entered into the InBody 520 scale. The InBody 520 scale computed BMI values, and subjects were placed in normal-weight (BMI = 18–24.9; n = 27) or obese (BMI ≥ 30; n = 27) groups. BMI was the criteria used to designate groups, as this marker can be computed using only height and weight when these are the only measurements available, as may be the case in some community settings.

Blood samples. Blood samples (0.5 ml) were drawn by trained phlebotomists, and serum 25(OH)D samples were analyzed in singlet by LCA using chemiluminescence (DiaSorin Liaison, Stillwater, MN). Serum 25(OH)D values were classified by the researchers based on the vitamin D status guidelines: <20 ng/ml = deficient; 21–29 ng/ml = insufficient; ≥30 ng/ml = sufficient (Holick, 2009).

Instrument development. To develop the vitamin D status screening tool, an extensive review of literature of over 65 articles was conducted. As part of the review, the American Dietetic Association Evidence Based Library was consulted; information from studies with "good/strong" to "fair" strength of evidence linking serum 25(OH)D levels to biological and/or behavioral factors (35 articles) was examined. Instrument items were developed based on a content analysis of articles reviewed; factors with clear evidence of relationship to vitamin D levels and those that could be assessed easily by lay persons in a self-report instrument were included.

Four graduate-level nutrition students provided feedback to establish face validity for the original 15 items, as recruitment was to be conducted on and around a university campus. Five registered dietitians established content validity through consensus on the selection of variables constituting items. They modified three items and provided two additional items for a final total of 17. Two registered dietitians with PhDs reexamined the revised tool for the clarity of terminology.

While 17 dichotomous (yes/no) items were included on the tool, some represented constants rather than variables for this sample. For example, differences in serum 25(OH)D by gender, skin pigmentation, and nonequatorial location were controlled for by limiting the sample to Caucasian women living in northern Illinois. All items were retained in the tool, as it is intended for eventual testing in more diverse groups and locations, but statistical testing was carried out using only those items with response variation equal to at least 10% of the sample.

Data Analysis

Statistical significance was set at $p \leq .05$. SPSS (SPSS version 17, SPSS, Inc., Chicago, IL) was used to analyze the data. Based on past literature (Parikh et al., 2004), it was anticipated that age would be related to serum 25(OH)D levels; therefore, ANCOVA using age as the covariate was performed to test for difference in 25(OH)D by weight group. Multivariate logistic regression with

dichotomous outcomes was used to assess the usefulness of assessment tool items in predicting risk for vitamin D inadequacy. Based on the vitamin D status guidelines (Holick, 2009), a dichotomous variable was created for vitamin D status (serum 25[OH]D ≥ 30 ng/ml, [sufficient] = *adequate*; serum 25[OH]D < 30 ng/ml, [insufficient or deficient] = *inadequate*), and subjects were classified based on the serum 25(OH)D. The *adequate–inadequate* terminology was chosen for the dichotomous variable over *sufficient–insufficient–deficient* to avoid confusion with the original terminology used in the guideline designations. *T* tests were used to test for differences in dietary and supplementary vitamin D intakes between weight groups.

RESULTS

The study included 54 healthy Caucasian women, aged 20–50, residing in northern Illinois. Sample mean (±*SD*) for age was 34 (±10) years, and for serum 25(OH)D was 23.8 (±10.6) ng/ml, a level indicating vitamin D inadequacy (Holick, 2009). Most (70%) had inadequate levels of vitamin D. When classified by weight group, both normal-weight subjects and obese subjects had mean (±*SD*) levels for serum 25(OH)D levels that indicated vitamin D inadequacy (29.2 [±9.6] ng/ml) and (18.5 [±8.7] ng/ml), respectively (Table 1). All three of the vitamin D sufficiency groups were significantly different from one another by serum 25(OH)D level, $F(2, 51) = 172.5$, $p < .001$ (Table 2). No significant differences were found for serum 25(OH)D levels between normal-weight and

TABLE 1: Differences by Weight Group in Serum 25(OH)D, Vitamin D Intake Through Diet and Supplements, and Use of Sunscreen

	Frequency (%)		*Mean (SD)*		*Use of sunscreen*		
Target variable	*Normal weight*	*Obese*	*Normal weight*	*Obese*	*No (n = 25)*	*Yes (n = 29)*	*t*
Serum 25(OH)D (ng/ml)			29.2 (±9.6)	18.5 (±8.7)			
Supplemental[a] Vitamin D (IU)			192.6 (339.6)	182.7 (122.8)			0.10 (n.s.)
0	19 (70)	19 (70)			18	20	
100–400	4 (15)	5 (19)			5	4	
800	3 (11)	1 (4)			1	3	
1,000	0 (0)	1 (4)			0	1	
1,200	1 (4)	0 (0)			0	1	
1,400	0 (0)	1 (4)			1	0	
Dietary[a] Vitamin D (IU)[b]			147.6 (120.9)	122.8 (123.7)			0.75 (n.s.)
100 or less	15 (56)	18 (67)			15	18	
101–200	2 (7)	4 (15)			4	2	
201–300	7 (26)	1 (4)			3	5	
301–400	1 (4)	3 (11)			2	2	
401–500	2 (7)	1 (4)			1	2	

NOTE: *n* = 27 (normal-weight group). *n* = 27 (obese group). Totals may not equal 100% because of rounding.

a. Dietary and supplemental averages were assessed using 3-day food records.

b. To convert IU to micrograms, multiply by 0.025.

TABLE 2: Comparison of Mean Serum 25(OH)D Concentration Categories By Body-Weight Group

	Vitamin D status (mean [SD])						
	Sufficient		*Insufficient*		*Deficient*		*F*
Serum 25(OH)D ng/ml	37.0 (±5.3)		25.7 (±2.5)		14.0 (±3.4)		172.5*
	Normal Weight	Obese	Normal Weight	Obese	Normal Weight	Obese	
n	13	3	8	6	6	18	

NOTE: Normal-weight group (n = 27); Obese group (n = 27).
*p < .001.

TABLE 3: Vitamin D Screening Tool Items Not Tested because of the Lack of Variation in Responses

Q2. I am African American, Latino, or of darker skin color than white Caucasian
Q3. I live in an area north of Florida
Q5. I work indoors most of the day during the work week
Q6. I have been diagnosed with osteoporosis or osteomalacia
Q8. I have a malabsorptive disorder (celiac disease, gluten intolerance, kidney disease, liver disease, Crohn's disease)
Q10. I experience frequent muscle or bone pain (osteoarthritis)
Q12. I have been diagnosed with, or have had, high parathyroid hormone levels in the past
Q13. I have an autoimmune disease (rheumatoid arthritis, hyperthyroidism, lupus, multiple sclerosis, psoriasis, etc.)
Q14. I have high blood pressure
Q15. I have had cancer
Q16. I have diabetes (type 1 or type 2)
Q17. I have been diagnosed with some form of heart disease

obese subjects based on the dietary vitamin D intake mean ± *SD* (147.6 ± 120.9 vs. 122.8 ± 123.7 IU) t = .75, p = .46, or supplementary vitamin D intake mean ± *SD* (192.6 ± 339.6 vs. 182.7 ± 122.8), t = .10, p = .92, respectively (Table 1). Combined dietary and supplemental vitamin D intake levels were well below the RDA of 600 IU/day for 81% of the participants (n = 44).

Five items yielded enough variation in responses (at least 10% of respondents) for testing as potentially useful predictors of vitamin D inadequacy: sunscreen use, dairy consumption, identification of self as obese, medication use, and fall–winter depression (see Table 3 for items included but not tested). Multivariate logistic regression analysis was used to predict the odds of exhibiting vitamin D inadequacy based on responses to the five dichotomous items. The test of the full model versus the intercept-only model was significant, (χ^2 [5, n = 54] = 43.24, p < .01). The model enabled us to classify accurately 92% of those who exhibited 25(OH)D inadequacy and 56% of those who did not, with an overall success rate of 82%. Of the five items tested, sunscreen use, dairy consumption, and obesity had significant partial effects (Table 4). The odds ratio for sunscreen use indicated that women who used sunscreen were over five times less likely to experience vitamin D inadequacy. To help explain this unexpected finding, additional tests for differences in dietary and supplemental vitamin D intake by sunscreen use were conducted. There were no significant differences in either dietary (t = −.59, p = .56) or supplemental (t = −.71, p = .48) vitamin D intake by sunscreen use. Also, the five participants

TABLE 4: Logistic Regression Predicting Vitamin D Inadequacy from Vitamin D Screening Tool Item Responses

Assessment tool item	*B*	*Wald* χ^2	*P*	*Odds ratio*
Q1. I regularly wear sunscreen with SPF 15 or greater when in the sun	1.71	4.03	.04	5.55
Q4. I eat fewer than the recommended 3 servings of dairy per day	−1.83	4.43	.03	6.25[a]
Q7. I am obese (BMI > 30)	2.36	4.65	.03	10.53[b]
Q9. I am taking one or more medicines...[c]	−0.31	0.12	.73	.73
Q11. I experience fall/winter depression	0.02	0.00	.98	1.02
Constant	−0.42	0.28	.60	0.66

a. Odds ratio inverted [1.0/0.160].
b. Odds ratio inverted [1.0/0.095].
c. Medicines listed included anticonvulsants to stop seizures (Dilantin, Luminal, Topamax, Valium), glucocorticoids (Celestone, Cortef, prednisone, Solu-Medrol), AIDS (HARRT), and antirejection medication for organ transplant (cyclosporine, prednisone, azathioprine) birth control medicine.

with total vitamin D intakes >1,000 IU were no more likely than other participants to have reported using sunscreen ($\chi^2 = 1.53$, $p = .22$).

For easier interpretation, odds ratios were inverted for dairy consumption and obesity. The odds of vitamin D inadequacy were six times higher for those consuming fewer than three dairy products/day and over 10 times higher for those reporting obesity. The odds of vitamin D inadequacy were not significantly different for those taking medications or for those who experience fall–winter depression (Table 4).

The preliminary ANCOVA test for homogeneity revealed that age was related to serum 25(OH)D, ($F[1, 53] = 7.77$, $p < .01$), but not to weight group, ($F[1, 53] = .08$, $p = .777$), providing evidence of no interaction between weight group and the covariate, age. The main ANCOVA indicated a significant relationship between serum 25(OH)D and age, ($F[1, 53] = 7.83$, $p < .01$). Additionally, there was a significant group effect when age was covaried out, ($F[1, 53] = 11.72$, $p < .01$). This indicated that obese subjects had significantly lower (mean ± *SD* serum 25(OH)D 18.49 ± 8.66 ng/ml) levels than did subjects in the normal-weight range (mean ± *SD* 29.19 ± 9.61 ng/ml), even after controlling for age.

DISCUSSION AND IMPLICATIONS

The purpose of this study was to validate selected items for a noninvasive vitamin D status screening tool for use in community health/wellness settings. The main findings were that vitamin D inadequacy was less likely for sunscreen users and more likely for obese individuals and those consuming fewer dairy products. The findings indicated the usefulness of the latter two indicators as part of the screening tool, and the need for refinements to the sunscreen-use item.

Those subjects who wore sunscreen regularly were over five times less likely to be vitamin D inadequate. This was unexpected, because topical application of sunscreen blocks up to 99% of vitamin D_3 synthesis (Gilchrest, 2008; Sayre & Dowdy, 2007). It was determined, however, that sunscreen users were not consuming more vitamin D through either diet or supplementation. Individuals who wear sunscreen likely experience more cumulative sun exposure, but may

not reapply sunscreen every two hours as recommended (Diffey, 2001). Additionally, researchers have found that sunscreen users typically apply about half the FDA-recommended quantity of sunscreen to achieve complete protection (Wolpowitz & Gilchrest, 2006). It is possible that subjects in this study either did not reapply sunscreen appropriately or did not use enough of the product, or both, with the result that exposure to the sun provided adequate vitamin D synthesis through the skin. Another possible explanation for this finding is that sunscreen users may be getting more outdoor exercise, hence lowering body mass, and leading to less sequestering of vitamin D in fat stores. Modification of the screening tool will include the assessment of outdoor exercise and more detail regarding the use of sunscreen.

Subjects consuming fewer than three servings of dairy/day were six times more likely to exhibit vitamin D inadequacy. As most dairy products are fortified with vitamin D (Moore, Murphy, & Holick, 2005), this suggests that daily consumption of at least three servings of dairy products makes a significant contribution to serum 25(OH)D levels. With respect to screening tool development, this finding provided evidence that self-report of dairy product consumption constitutes an appropriate assessment indicator. In the revised screening tool, the words "the recommended" (three servings a day) have been removed from the dairy item to reduce the possible introduction of bias.

Individuals who self-identified as obese were 10 times more likely to be inadequate in vitamin D. BMI computations verified the truthfulness of self-reporting of obesity status, as 93% of participants reported accurately. The important point here is that this lends credence to the item's usefulness on the vitamin D status screening tool when height and weight cannot be measured. For example, in some community settings, such as feeding centers, instruments for measuring height and weight may not be available.

Additional statistical testing was conducted to verify that the higher odds of vitamin D inadequacy in obese women were not confounded by age. Obese subjects had significantly lower mean serum 25(OH)D levels than did subjects in the normal-weight range, even after controlling for age. This indicates that the obesity item is an appropriate indicator for inclusion on the screening tool, regardless of the respondents' age.

The study provided information important to the modification of the vitamin D status screening tool. Refinements should include increased precision for the indicator related to the use of sunscreen. Items related to the use of tanning devices, vitamin D supplementation, age, and participation in outdoor activities also should be added.

Significant limitations to this study were a small sample size, which reduced power and limited generalizability of findings and the disparity in supplemental vitamin D intake among the participants. Additionally, the sample represented a homogeneous group of Caucasian women living in a northern climate, which limited the applicability of the screening tool. In the sunscreen-use item, subjects may not have been certain what "regularly" meant; this point is important to the development of the screening tool, as it indicates the need to include additional questioning about regularity of use and reapplication of sunscreen.

This pilot study provided initial verification of specific indicators useful on a vitamin D status screening tool. Obesity and consumption of dairy products were the most useful indicators. To expand testing of the screening tool for

validity and reliability, a larger, less homogeneous sample is needed. For example, because it is known that melanin pigmentation reduces the synthesis of vitamin D in skin and that insufficient vitamin D is produced by skin during winter months in nonequatorial regions (Holick, 2006), additional testing of the screening tool is needed using larger samples that include individuals with different skin pigmentation and those residing in differing latitudes. Following refinement in precision of items and further testing with different, larger samples, the instrument may prove useful and cost-effective in community health/wellness settings as a vitamin D screening tool.

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