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Vitamin D concentrations among older adults according to physical disability status: NHANES 2007-2014

10.20960/nh.2507

OR 2507

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Received: 13/01/2019
Accepted: 04/03/2019
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ABSTRACT

Background: older adults are at increased risk of vitamin D deficiency as a result of limited sun exposure and inadequate vitamin D intake. Despite this evidence, there are scarce data regarding the concentration of 25(OH)D and its metabolites among older adults with physical disability.
Methods: the National Health and Nutrition Examination Survey 2007-2014 data were collected to compare 25(OH)D_3, 25(H)D_2, and total 25(OH)D concentrations among adults aged 60 years and older with and without physical disability. Moreover, general linear models adjusted for potential confounders were used to examine the independent effect of vitamin D intake, physical activity status and body mass index (BMI) categories on 25(OH)D concentrations by disability status.
Results: of 6,250 older adults, 17.9% were defined as physically disabled. 25(OH)D concentrations were 71.3 and 78.2 nmol/l in subjects with and

without disability, respectively. However, after adjustment for potential confounders, similar 25(OH)D concentrations were seen between disabled subjects and their non-disabled counterparts (75.6 *vs* 77.5 nmol/l; p = 1.17). In contrast, older adults with disability had significantly increased 25(OH)D_2 concentrations (8.3 *vs* 6.1 nmol/l; $p < 0.05$). Notably, older adults with a daily vitamin D intake of ≥ 15 mcg achieved sufficient 25(OH)D concentrations, regardless of their disability status.

Conclusion: 25(OH)D concentrations did not significantly differ among older adults by disability status. This finding was attributed to increased 25(OH)D_2 concentrations among those with physical disability. Thus, adequate vitamin D intake is an effective strategy to maintain sufficient 25(OH)D concentrations, particularly among disabled older adults.

Key words: Older adults. Physical disability. Vitamin D concentrations.

RESUMEN

Antecedentes: los adultos mayores tienen mayor riesgo de deficiencia de vitamina D debido a una limitada exposición al sol e ingesta inadecuada de vitamina D. A pesar de esto, existen escasos datos sobre la concentración de 25(OH)D y sus metabolitos en adultos mayores con discapacidad física.

Métodos: la Encuesta Nacional de Salud y Nutrición de 2007-2014 se analizó para comparar las concentraciones de 25(OH)D_3, 25(OH)D_2 y 25(OH)D total entre los adultos mayores con y sin discapacidad física. Se usaron modelos generalizados lineales ajustados por cofactores para examinar el efecto independiente de la ingesta de vitamina D, los niveles de actividad física y las categorías del índice de masa corporal (IMC) sobre las concentraciones de 25(OH)D por condición de discapacidad.

Resultados: de un total de 6.250 adultos mayores, el 17,9% tenía discapacidad física. Las concentraciones de 25(OH)D fueron 71,3 y 78,2 nmol/l en sujetos con y sin discapacidad, respectivamente. Sin embargo, después del ajuste por covariables, niveles similares de 25(OH)D fueron observados entre los sujetos con discapacidad y sus homólogos sin discapacidad (75,6 *vs.* 77,5 nmol/l; p = 1,17). En contraste, las concentraciones de 25(OH)D_2 fueron significativamente mayores en los sujetos con discapacidad física (8,3 *vs.* 6,1 nmol/l; $p < 0,05$). En particular, los sujetos con una ingesta diaria de vitamina D de ≥ 15 mcg alcanzaron niveles adecuados de 25(OH)D, a pesar de su condición de discapacidad.

Conclusión: las concentraciones de 25(OH)D fueron similares entre los adultos mayores por condición de discapacidad. Este hallazgo fue atribuido al aumento de la concentración de 25(OH)D_2 entre las personas con discapacidad física. Así, la ingesta adecuada de vitamina D es una estrategia efectiva para mantener niveles óptimos de 25(OH)D, particularmente entre los adultos mayores con discapacidad.

Palabras claves: Adultos mayores. Discapacidad física. Vitamina D.

INTRODUCTION

Older adults are at increased risk of developing 25-hydroxyvitamin D (25[OH]D) deficiency as a result of inadequate dietary vitamin D intake and decreased sun exposure (1). Aging also reduces the concentration of 7-dehydrocholesterol in the epidermis and the total production of previtamin D_3 after exposure to solar ultraviolet B radiation (2). Moreover, it has been postulated that low 25(OH)D levels may accelerate the disablement process through both direct effects on muscular function as well as indirectly through its association with chronic conditions such as diabetes, hypertension, cardiovascular disease, impaired pulmonary function and arthritis, which are frequent causes of declines in physical function (3,4).

Previously, a few cross-sectional studies reported that lower 25(OH)D concentrations among older adults were associated with increased risk of functional limitations and physical disability (5-10). For instance, participants in the Cardiovascular Health Study All Starts with 25(OH)D deficiency and insufficiency had about 50% higher odds of having prevalent limitations in activities of daily living (ADL) at baseline than those with sufficient 25(OH)D levels (6). Likewise, lower 25(OH)D concentrations were described in older adults with ADL limitations compared with their non-disabled counterparts (5,9,10). Indeed, Nakamura et al. reported that limitation in ADL was the most reliable predictor of serum 25(OH)D concentrations among older adults in Yamato, Japan (10). However, these latter studies were limited by incomplete assessment of dietary vitamin D intake and small sample sizes (5,9,10). Thus, the aims of the present study were to compare the concentrations of 25(OH)D and its active metabolites in a nationally representative sample of older adults with and without disability and to examine the independent effect of BMI categories, physical activity status, and vitamin D intake on 25(OH)D concentrations according to disability status.

METHODS

The NHANES is a biannual cross-sectional study conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention. The purpose of the NHANES is to collect data about the health, nutritional status and health behaviors of the noninstitutionalized civilian resident population of the United States (U.S.). The NHANES data were obtained using a complex, multistage probability sampling design to select a sample representative of the U.S. civilian noninstitutionalized household population (11). For this analysis, the NHANES data for the cycles 2007-2014 (n = 40,617) were selected. Of those 7,859 subjects were aged 60 years and older. Participants who were only interviewed (n = 337) and had missing data on BMI (n = 514), ADL (n = 20), dietary vitamin D intake or supplements (n = 945) and 25(OH)D concentrations (n = 990) were excluded, leaving a total sample size of 6,250 subjects. Overall, participants with missing data were more likely to be women, non-Hispanic white, have less than high school education, drink alcohol, and be physically inactive.

Demographic and behavioral characteristics

All participants who completed a household interview record were included in the Demographics file. The six-month time period when the examination was performed (November 1st through April 30th and May 1st through October 31th), age, gender, race/ethnicity (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and other race), education (< high school, high school/GED equivalent, some college or AA degree, college graduate or above), and the ratio of family income to poverty threshold as a measure of socioeconomic status were reported. In the mobile examination center, the body mass index (BMI) was calculated as body weight (kilograms) divided by height (meters squared) and reported in kg/m^2. BMI was grouped into underweight and normal weight (< 25 kg/m^2), overweight (25.0 to 29.9 kg/m^2) and obesity (≥ 30 kg/m^2). Participants also reported their smoking status and were classified as current, former and never smokers. Subjects were considered as alcohol users if they responded affirmatively to the question "In any one year, have you had at least 12 drinks of any type of alcoholic beverage? By a drink, I mean a 12 oz. beer, a 5 oz. glass of wine, or one and half ounces of liquor".

The physical activity questionnaire is based on the global physical activity questionnaire. Participants were considered to perform vigorous leisure-time physical activity if they responded affirmatively to the question "Do you do any sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least ten minutes continuously?" Likewise, subjects were considered to engage in moderate recreational activities if they affirmatively responded to the question "Do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or golf for at least ten minutes continuously?" The reported number of days and time in minutes spent performing vigorous or moderate leisure-time physical activity in the previous week were calculated. Based on the 2008 Physical Activity Guidelines for Americans, three levels of physical activity were created: a) participants who engaged in ≥ 150 min/week of moderate activity, or ≥ 75 min/week of vigorous activity, or ≥ 150 min/week of an equivalent combination were defined as physically active; b) insufficiently active were considered those who reported some physical activity, but no enough to meet the active definition (> 0 to < 150 min/week); and c) inactive if they reported no physical activity (12).

Dietary and supplement vitamin D intake

The NHANES dietary intake data were used to estimate the types and amounts of foods and beverages consumed during the 24-hour period prior to the interview, and to estimate intakes of energy, nutrients, and other food components from those foods and beverages. Since the NHANES wave 2007-2008, vitamin D has been added to the list of nutrients. The vitamin D values in this dataset reflect the sum of ergocalciferol ($25[OH]_2$) and cholecalciferol ($25[OH]D_3$) content of foods reported by survey participants. The 24-hour dietary supplement interview was collected following the 24-hour dietary recall. All NHANES examinees responding to the dietary recall interview were eligible for the dietary supplement and antacid use questions. Information was obtained on all vitamins, minerals, herbals and other dietary supplements that were consumed during a 24-hour time period, including the name and the amount of dietary supplement taken. Since 2007-2008, vitamin D supplements $25(OH)D_2$ and $25(OH)D_3$ were reported to estimate participants' consumption of vitamin D supplements during the 24-hour period. For the present analysis, vitamin D intake from the dietary and supplement components were combined to estimate the total daily dietary intake of vitamin D (13).

Physical disability

The NHANES physical functioning section provides self-reported data on functional limitations caused by long-term physical, mental, and emotional problems or illness. Participants were asked: "By yourself and without using any special equipment, how much difficulty do you have walking from one room to another on the same level; getting in or out of bed; eating like holding a fork, cutting food, or drinking from a glass; dressing including tying shoes, working zippers, and doing buttons?" Subjects who reported some difficulty, much difficulty, or were unable to do any of these basic ADL were defined as having physical disability. Of note, the NHANES did not have information on bathing or toileting during the study period (14). Moreover, participants reported the condition or health problem associated with limitations in ADL.

Total 25(OH)D, $25(OH)_3$ and $25(OH)D_2$ concentrations

The CDC standardized liquid chromatography-tandem mass spectrometry (LC-MS/MS) method was used for measurement of 25(OH)D for NHANES 2007-2014, which allows laboratories and surveys to compare 25(OH)D measurements. The CDC decided to develop a LC-MS/MS method traceable to the NIST-reference materials for NHANES, and used this method starting with NHANES 2007-2008 to measure $25(OH)D_3$, $25(OH)D_2$ and the C3 epimer of $25(OH)D_3$. For the CDC LC-MS/MS method, total 25(OH)D (in SI units of nmol/l) was defined as the sum of $25(OH)D_3$ and $25(OH)D_2$ and excluded the C3 epimer of $25(OH)D_3$. However, due to rounding, the sum of $25(OH)D_3$ and $25(OH)D_2$ will not necessarily be equal to the 25(OH)D. The CDC recommends using the total 25(OH)D in SI units (nmol/l) measured directly by LC-MS/MS and converting this quantity to conventional units (1 nmol/l = 0.4066 ng/ml), if needed. This method has better analytical specificity and sensitivity compared to immunoassay methods, and fixed analytical goals for imprecision ($\leq$ 10%) and bias ($\leq$ 5%) (15).

Statistical analysis

The descriptive characteristic of the study population was reported as percentages and mean values with their respective standard errors. The Chi-square and t-tests for categorical and continuous variables were used to compare demographic, behavioral, and nutritional characteristics of the participants stratified by disability status, respectively. General linear models according to six-month time period, as a surrogate for seasons (November 1st through April 30th and May 1st through October 31th) were created to compare mean 25(OH)D, 25(OH)D_3, and 25(OH)D_2 levels between older adults defined as having physical disability and those who did not. The following potential confounders were included in the adjusted models: age, gender, race/ethnicity, education, ratio of family income to poverty, BMI, smoking status, alcohol consumption, physical activity, and total daily vitamin D intake. Subgroup analyses were conducted to assess the independent effect of BMI categories, physical activity status, and tertiles of vitamin D intake on 25(OH)D concentrations in older adults with and without disability. Statistical analyses were performed using SPSS Complex Sample software, V.17 (SPSS Inc., Chicago, Illinois, U.S.) to incorporate constructed weights for the combined survey cycles and obtain unbiased, national estimates representative of the older U.S. population (16).

RESULTS

A total of 6,250 participants with a mean age of 69.6 (SE 0.1) years comprised the study sample, representing an estimated 48 million older adults in the U.S. during the study period. Of these, 1,404 (17.9%) subjects were defined as having physical disability. Table I shows the demographic, behavioral and nutritional characteristics of the participants stratified by disability status. In general, subjects with physical disability tended to be older, women, less educated, had lower socioeconomic status, and increased BMI compared with their non-disabled counterparts. Notably, 75.5% of disabled older adults were physically inactive. In general, about 79% of U.S. older adults obtained their daily vitamin D intake through supplements and the mean 25(OH)D concentration was 76.9 (0.7) nmol/l. Moreover, participants with physical disability had significantly lower 25(OH)D_3 and 25(OH)D concentrations than those who did not. In contrast, higher 25(OH)D_2

levels were consistently seen among disabled older adults. Overall, arthritis/rheumatism and back or neck problem accounted for 50.9% and 19.1% of the reported health conditions associated with physical disability, respectively.

As shown in table II, similar 25(OH)D concentrations and its forms were seen among older adults by disability status category between November 1st and April 30th. In contrast, non-disabled older adults had higher 25(OH)D_3 concentrations than those with disability between May 1st and October 31st. Similarly, participants with disability had increased 25(OH)D_2 concentrations during the same study period. Moreover, after adjustment for six-month time periods, non-disabled and disabled participants had significantly higher 25(OH)D_3 and 25(OH)D_2 concentrations, respectively. However, in the final model, total 25(OH)D concentrations did not significantly differ by disability status.

As shown in figure 1, 25(OH)D concentrations significantly decreased across BMI categories, which was more accentuated among disabled subjects. For instance, obese non-disabled and disabled participants had 9.2 and 12.2 nmol/l lower 25(OH)D concentrations compared with their normal-weight counterparts, respectively. As shown in figure 2, 25(OH)D concentrations significantly increased only among non-disabled subjects defined as physically active. However, physically active disabled older adults had on average 6.9 nmol/l higher 25(OH)D concentrations than those with sedentary lifestyle. As shown in figure 3, 25(OH)D concentrations markedly increased as dietary vitamin D intake also increase, irrespective of the disability status. Notably, non-disabled and disabled participants with a daily vitamin D intake $>$ 15 mcg had increased 25(OH)D concentration at 91.4 and 89 nmol/l, respectively.

DISCUSSION

The results of the present study indicate that overall U.S. older adults with physical disability had lower 25(OH)D_3 and 25(OH)D concentrations than their non-disabled counterparts. However, after adjustment for potential confounders, total 25(OH)D concentrations did not significantly differ according to disability status. In general, 25(OH)D_3 concentrations remained lower among participants with disability, particularly between May 1st and October 31st. On the contrary, higher 25(OH)D_2 concentrations were consistently seen among disabled older adults during the study period. The present results contrast with those from prior studies in which significantly lower 25(OH)D levels were described among older adults with disability in ADL (5,9,10). Possible explanations for these contradictory results may be related to higher 25(OH)D_2 concentrations present among subjects with physical disability, which has not been previously reported. Moreover, dietary vitamin D intake was not completely assessed as a major determinant of vitamin D status, particularly in older adults with disability. For instance, Nakamura et al. reported the frequency of fish consumption as a surrogate of vitamin D intake among older Japanese with various levels of physical disability (10). Likewise, among participants in the Women's Health and Aging Study I, which included women with ≥ 2 domains of disability, the prevalence of vitamin D deficiency defined by a serum 25(OH)D level < 25 nmol/l ranged between 9.2% and 14%. However, vitamin D intake was not assessed in that particular study.

Notably, increased 25(OH)D concentrations were seen among older adults with and without disability who consumed vitamin D > 15 mcg per day. In contrast, participants with a daily vitamin D intake between 0 and 3.7 mcg had on average 50% lower 25(OH)D concentrations than those with adequate vitamin D intake, irrespective of their disability status. Thus, the present findings suggest that a daily vitamin D intake of > 15 mcg is an effective strategy for maintaining 25(OH)D concentrations > 75 nmol/l, particularly in disabled older adults. Of interest, most of the U.S. older adults obtained their dietary vitamin D intake from supplements, which accounted for 79% of the total dietary vitamin D intake. Although there is a general consensus that 25(OH)D_2 is only present in populations consuming sun-dried and UVB light-exposed mushrooms or 25(OH)$_2$ supplements, a recent analysis of the National Adult Survey in Ireland reported that 25(OH)D_2 was present in the diet of the majority of adults, at variable but possibly nutritionally relevant levels (17). Similarly, the increased 25(OH)D_2 concentrations found particularly among disabled older adults indicate that 25(OH)D_2 consumption obtained from food or supplements may also represent an important source of dietary vitamin D in older U.S. adults. Barake et al. previously reported that among participants in the NuAge study conducted in Quebec, Canada, the mean vitamin D intake from food and supplements was 14.1 mcg/day among those with vitamin D status > 75 nmol/l, which is also consistent with the present results (18). In addition, the Institute of Medicine dietary recommendations of vitamin D ≥ 15 mcg among individuals aged 50 years and older should be considered as adequate to maintain sufficient 25(OH)D concentrations (> 75 nmol/l) among disabled older adults (19).

Although it is well documented that sunlight exposure is a main determinant of vitamin D status, this variable was not specifically evaluated in the NHANES cycles 2007-2014 (20,21). However, previous studies have documented that the relationship between physical activity and circulating 25(OH)D concentrations mostly reflect the effect of sunlight exposure during outdoor physical activity (22,23). Indeed, a recent study reported that U.S. older adults physically active had on average 8.1 and 7.1 nmol/l higher 25(OH)D and 25(OH)D_3 concentrations than those with sedentary lifestyle, respectively. Moreover, the increased 25(OH)D_3 concentration seen among subjects physically active indicate that sunlight exposure is important to achieve sufficient 25(OH)D status in older U.S. adults (24). Despite this evidence, about two-thirds of U.S. older adults with physical disability did not meet physical activity guidelines, which may explain a non-significant linear increase in 25(OH)D concentrations according to physical activity status.

As expected, BMI categories had an effect on 25(OH)D concentrations among older adults, irrespective of their disability status. For instance, after adjustment for potential confounders, obese subjects with and without disability had on average 12.2 and 9.2 nmol/l lower 25(OH)D concentrations compared with their normal-weight counterparts, respectively. Moreover, the mean 25(OH)D concentration difference by disability status increased from 3.6% among participants with normal weight to 8.5% among those considered obese. This inverse association between obesity and low vitamin D status has been explained by decreased bioavailability of vitamin D as a result of sequestration of vitamin D by the adipose tissue, dilution of vitamin D in the large fat mass of obese people and reduced sun exposure (25). Thus, obese older adults with disability should be encouraged to maintain a healthy weight to improve their 25(OH)D status.

Overall, arthritis/rheumatism was the leading cause of physical disability among U.S. older adults, which is in agreement with previous reports (26,27). Moreover, a recent study among participants in the Mexican Health and Aging Study demonstrated that older adults with arthritis and vitamin D insufficiency were three times as likely to have physical disability as compared with their normal counterparts (28). Thus, further studies should be conducted to examine the relationship between arthritis attributable physical disability and 25(OH)D concentrations among older adults.

Several limitations should be considered while interpreting the present findings. First, because of the NHANES survey cross-sectional design, the study results do not necessarily infer causation. Second, participants self-reported their ADL limitations, which may have been subject to recall bias. Third, subject's sunlight exposure or use of sunscreen was not evaluated in this analysis. Fourth, the effect of latitude on participants' 25(OH)D concentrations was unknown. Fifth, the association between physical disability and 25(OH)D concentrations was limited to non-institutionalized older adults. However, a small cross-sectional study conducted among newly admitted nursing home patients in Honolulu, Hawaii, reported that vitamin D deficiency was significantly associated with the number of ADL disabilities (29). Finally, the present findings may be only generalizable to physically disabled older adults with similar sociodemographic characteristics and dietary vitamin D intake.

In conclusion, similar 25(OH)D concentrations were seen among U.S. older adults according to disability status. This finding was predominantly attributed to increased $25(OH)D_2$ concentrations in subjects with physical disability. Thus, adequate vitamin D intake is an effective strategy to maintain sufficient 25(OH)D concentrations among disabled older adults.

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Table I.

	Total (n = 6,250)	*Non-disability* (n = 4,846)	*Disability* (n = 1,404)	*p value*
Six-month time period,%				0.266
Nov 1st to April 30th	38.3 (3.3)	37.9 (3.3)	40.3 (3.7)	
May 1st to Oct 31st	61.7 (3.3)	62.1 (3.3)	59.7 (3.7)	
Age (years), mean	69.6 (0.1)	69.2 (0.1)	71.2 (0.2)	< 0.0001
Gender, %				< 0.05
Male	45.5 (0.7)	46.4 (0.7)	41.6 (1.7)	
Female	54.5 (0.7)	53.6 (0.7)	58.4 (1.7)	
Race/ethnicity, %				< 0.0001
Mexican-American	3.9 (0.6)	3.3 (0.5)	6.7 (1.3)	
Other Hispanics	3.3 (0.5)	2.9 (0.4)	5.0 (0.8)	
Non-Hispanic white	80.6 (1.4)	82.4 (1.2)	72.2 (2.3)	
Non-Hispanic black	7.9 (0.8)	7.3 (0.7)	10.7 (1.1)	
Other race	4.4 (0.4)	4.1 (0.5)	5.5 (0.8)	
BMI (kg/m^2), mean	29.0 (0.1)	28.6 (0.1)	30.9 (0.2)	< 0.0001
Education,%				< 0.0001
Less than high school	20.3 (1.1)	18.0 (1.1)	31.2 (1.9)	
High school graduate/GED	23.8 (0.8)	23.4 (0.9)	25.3 (1.3)	
Some college or AA degree	28.8 (0.9)	28.8 (1.1)	28.9 (1.8)	
College graduate or above	27.1 (1.3)	29.8 (1.5)	14.6 (1.5)	
Income to poverty ratio, %				< 0.0001
≥ 1.00	90.7 (0.6)	92.6 (0.5)	81.9 (1.4)	
< 1.00	9.3 (0.6)	7.4 (0.5)	18.1 (1.4)	
Smoking status, %				< 0.05
Never	49.1 (1.0)	50.0 (1.0)	45.4 (1.9)	
Former	40.3 (0.8)	39.9 (0.9)	42.2 (1.7)	
Current	10.6 (0.5)	10.2 (0.6)	12.3 (1.1)	
Alcohol consumption, %				< 0.0001
Yes	69.4 (1.1)	70.6 (1.2)	63.8 (1.7)	
No	30.6 (1.1)	29.4 (1.2)	36.2 (1.7)	
Physical activity, %				< 0.0001
None	56.4 (1.2)	52.2 (1.3)	75.5 (1.5)	
< 150 min/week	15.7 (0.6)	17.0 (0.7)	9.8 (1.1)	
≥ 150 min/week	27.9 (1.0)	30.8 (1.2)	14.7 (1.4)	
Dietary vitamin D intake (mcg), mean	4.7 (0.08)	4.8 (.09)	4.3 (0.1)	< 0.05
Vitamin D supplements (mcg), mean	17.9 (1.0)	17.6 (1.1)	19.1 (3.4)	0.680
Total vitamin D intake (mcg),	22.7 (1.1)	22.5 (1.1)	23.5 (3.4)	0.789

mean				
25(OH)D_3 (nmol/l), mean	70.6 (0.8)	72.2 (0.8)	63.2 (1.2)	< 0.0001
25(OH)D_2 (nmol/l), mean	6.3 (0.4)	6.0 (0.4)	8.1 (0.8)	< 0.05
25(OH)D (nmol/l), mean	76.9 (0.7)	78.2 (0.8)	71.3 (1.2)	< 0.0001

Parenthesis represents standard error of the estimates.

Table II.

Vitamin D levels (nmol/l)	*Non-disability*	*Disability*	*Vitamin D nmol/l difference*	*p value*
Nov 1st to April 30th				
25(OH)D_3	67.8 (1.0)	65.6 (1.7)	-2.1 (1.9)	0.057
25(OH)D_2	6.5 (0.9)	7.8 (1.2)	1.3 (1.7)	0.448
25(OH)D	74.3 (1.2)	73.5 (1.8)	-0.8 (2.0)	0.689
May 1st to Oct 31st				
25(OH)D_3	73.6 (0.9)	68.6 (1.8)	-4.9 (1.8)	< 0.001
25(OH)D_2	5.8 (0.5)	8.5 (1.2)	2.6 (1.2)	< 0.05
25(OH)D	79.4 (0.8)	77.1 (1.3)	-2.3 (1.4)	0.124
*Combined periods**				
25(OH)D_3	71.4 (0.7)	67.3 (1.3)	-4.1 (1.3)	< 0.05
25(OH)D_2	6.1 (0.5)	8.3 (0.8)	2.2 (0.9)	< 0.05
25(OH)D	77.5 (0.7)	75.6 (1.1)	-1.9 (1.1)	0.117

Models adjusted for age, gender, race/ethnicity, education, income to poverty ratio, BMI, smoking, alcohol consumption, physical activity status, and total vitamin D intake. *Models also adjusted for six-month time periods.

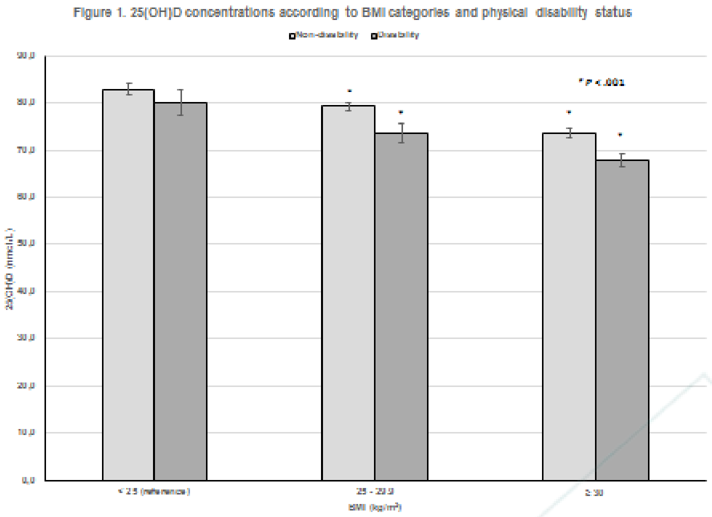

Fig. 1. 25(OH)D concentrations according to BMI categories and physical disability status.

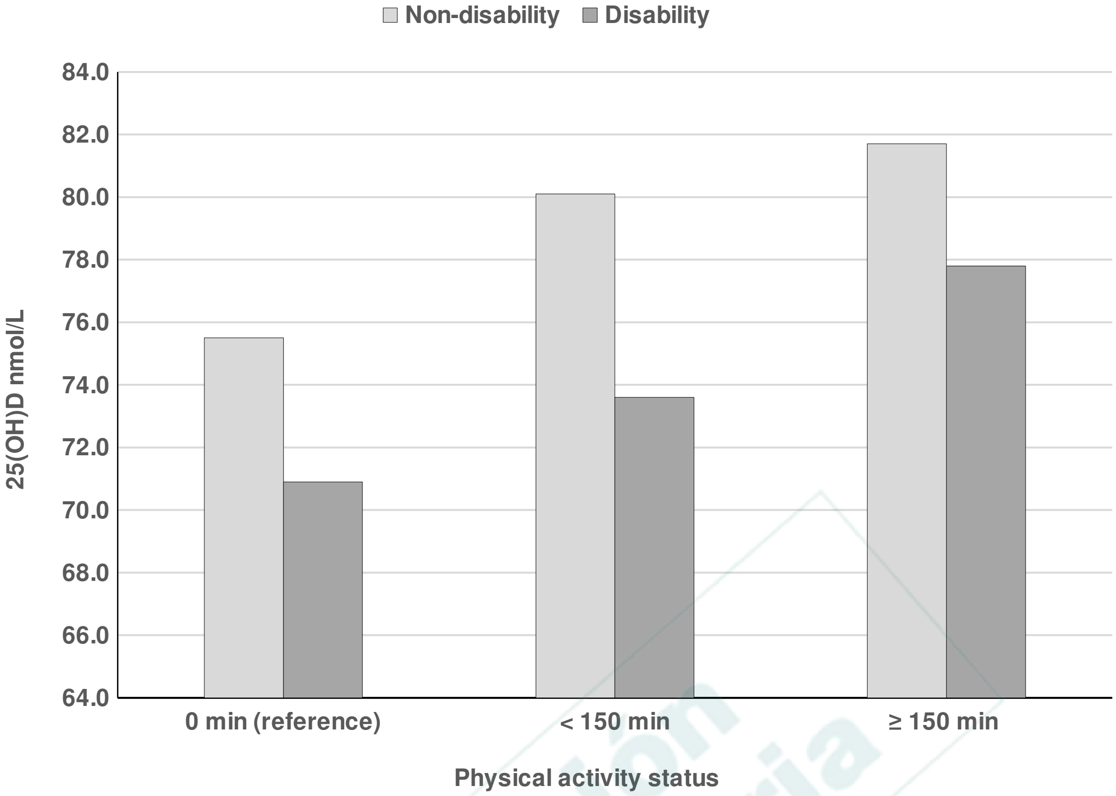

Fig. 2. 25(OH)D concentrations according to physical activity and disability status.

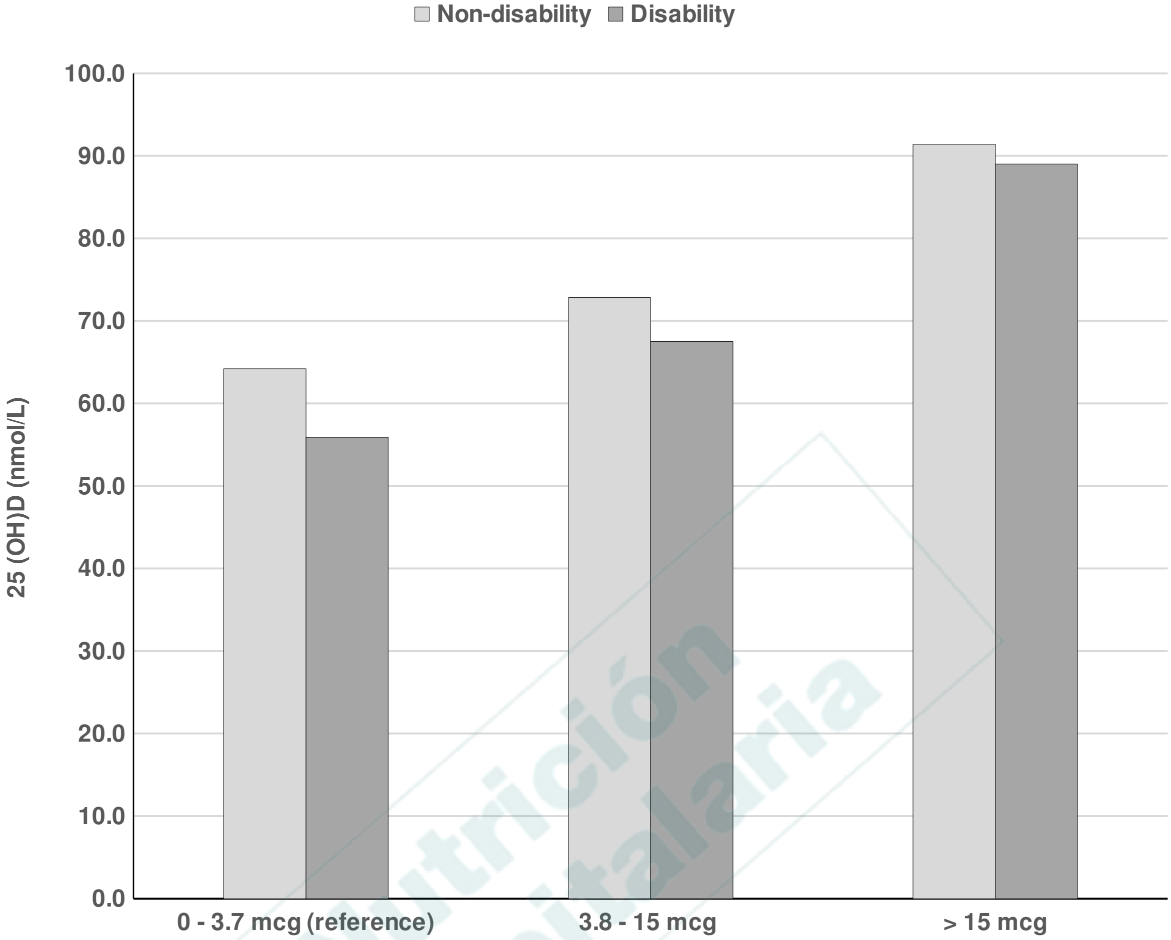

Fig. 3. 25(OH)D concentrations according to daily vitamin D intake and disability status.