Association between Vitamin D Levels and Blood Pressure in a Group of Puerto Ricans

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Objective: Hypertension is a global public health problem. The apparent association between vitamin D (VitD) and blood pressure (BP) has been studied in several populations but not in a Puerto Rican population. Therefore, we determined the association between serum 25(OH)D levels and BP in a convenience sample in Puerto Rico.

Methods: A cross-sectional study of patients attending a local laboratory with an order for serum 25(OH)D levels was performed. Participants completed a questionnaire that solicited the following information: age, sex, weight, height, VitD intake, and history of both sun exposure and hypertension. BP was measured by a phlebotomist on-site and classified according to the Joint National Committee; serum 25(OH)D levels were taken from the record, and VitD status was classified as either *optimal* (25(OH)D ≥30 ng/dl) or *non-optimal* (<30ng/dl). Mean, standard deviation, and percentiles were used for descriptive analysis. VitD status and BP were compared by gender, age, and body mass index (BMI) using ANOVA or chi-square. The association between VitD status and blood pressure was assessed by polytomous logistic regression adjusting for several variables.

Results: Two hundred nineteen individuals were included in the analysis; most were females aged 21 to 50 years who were overweight/obese; 53% of the total population was pre-hypertensive or hypertensive; 60% had non-optimal VitD status; and the sun exposure index was 19.6. No significant associations were found between VitD status and blood pressure after adjusting for age, sex, BMI, total VitD intake, and solar exposure index.

Conclusion: VitD status was not found to be associated with blood pressure in this sample population; more studies with a larger sample population are needed to determine whether such an association does in fact exist. [*P R Health Sci J 2012;3:123-129*]

Key words: Vitamin D levels, Blood pressure, Puerto Rico

Cardiovascular diseases are among the main causes of mortality in both men and women in the US. Over 61 million Americans have some cardiovascular-related condition (1). Cardiovascular conditions include hypertension, heart disease, stroke, and congestive heart failure, among others. Hypertension is a growing public health problem. By 2025 it is expected that 1.6 billion people worldwide will have hypertension (2). According to statistics from 2003, the overall prevalence of hypertension in Puerto Rico was 27% (29% in women and 26% in men) (3).

Hypertension leads to changes in calcium homeostasis including a decrease in calcium absorption in the gut, an increase in urinary calcium excretion, a reduction of serum calcium levels, and an increase in intracellular calcium (4). Some of these changes depend on the intracellular enzyme adenylate cyclase, which is itself influenced by $1,25(OH)_2D$ (the active form of vitamin D) (4). Several studies have recently found an association between vitamin D levels and blood pressure (2, 5).

Vitamin D is a fat-soluble vitamin that acts as a precursor hormone, and its primary role is the maintenance of calcium homeostasis. It is present in only a few foods naturally, such as fish and some mushrooms, and in foods fortified with vitamin D (6). However, the major source of vitamin D is due to the exposure of the skin to ultraviolet-B (UVB) rays (7). Vitamin D from either source —that acquired from foods (which is absorbed in the intestine with fat, incorporated

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into chylomicrons, and transported to the liver via the lymphatics) and that acquired through endogenous synthesis as a result of sun exposure (which is first converted to 7-dehydrocholesterol [as a previtamin] and then transported to the liver)— is hydrolyzed in the liver into 25(OH)D and then into the active form, 1,25$(OH)_2$D, in the kidneys. There is a high prevalence of low VitD status worldwide (8), even in countries in the lower latitudes, where it has generally been assumed that UVB radiation is sufficient to prevent vitamin-D deficiency, and in industrialized countries, where vitamin-D fortification of foods has been in place for years. According to NHANES, 70% of the US population suffers from some level of vitamin D insufficiency (9). A recent study of 358 Hispanic men residing in the US found a high prevalence of vitamin D deficiency in Puerto Ricans (26%) compared with Dominicans (21%), Central Americans (11%), and South Americans (9%) (10). Most recently, in a group of local obese Puerto Ricans, 31% had insufficient VitD status and 14% had deficient VitD status (11).

In the past, vitamin D deficiency was associated only with bone disease. However, in recent years studies have found that it is also associated with high blood pressure (12), higher serum cholesterol and triglyceride levels (13), glucose intolerance, insulin resistance and risk of diabetes (14), high inflammatory markers (15, 16), and an increased risk of cardiovascular events (17). A deficiency of vitamin D increases the levels of parathyroid hormone, which increase is associated with these conditions as well (18). In addition, the discovery of vitamin D receptors (VDR) in different body organs explains how vitamin D is directly involved with other tissues other than bone (19). VDRs are involved in regulating the expression of renin, which, together with angiotensin, is an important system in the regulation of blood pressure (20). Furthermore, vitamin D deficiency affects the expression of renin, which could cause hypertension (20).

Therefore, the main objective of this study was to determine whether or not there is an association between serum 25(OH)D levels and blood pressure in a convenience sample of Puerto Ricans. As of this writing, no study showing a definitive link between vitamin D levels and blood pressure in a Puerto Rican population (living on the island) has been published.

Methods

Population

A convenience sample of individuals was recruited from a local laboratory in northeastern Puerto Rico. Recruited from January to May 2011, this convenience sample was composed of individuals who had visited the lab in question with the intention of having their 25(OH)D levels measured (as per a doctor's order). Additional inclusion criteria were that the potential participant be older than 21 years and that he or she provide consent to take part in the study. The study was approved by the administration of the local laboratory and by the Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico.

Procedures

Participants first completed a questionnaire that included four sections: [1] demographic and body composition data, [2] frequency of consumption of foods rich in vitamin D, [3] sun exposure history, and [4] blood pressure history. Each questionnaire was identified with the given patient's laboratory record number. Subsequently, a nurse phlebotomist measured blood pressure with a sphygmomanometer and took the samples corresponding to the physician's order and in which 25(OH)D serum levels were measured.

Demographic and body composition data

Age, gender, weight, and height were self-reported by the subjects. Body mass index (BMI) was calculated using the following formula: kg/m^2. Subjects were classified, according to their BMIs, as normal (BMI<25 kg/m^2), overweight (BMI = 25-29 kg/m^2), or obese (BMI ≥30 kg/m^2) (21).

Food Frequency Questionnaire (FFQ)

A semi-quantitative FFQ focusing on foods and supplements rich in vitamin D was prepared. The semi-quantitative FFQ was composed of 22 items that were considered to be potential sources of vitamin D in the population of interest. This questionnaire was previously used in a sample of Puerto Rican adults, and results showed a significant correlation between vitamin D intake estimated from this questionnaire and serum 25(OH)D levels (11). Not all of the foods listed in the questionnaire were considered to be significant sources of vitamin D; however, those that were also included an open-ended follow-up question inquiring as to the specific products consumed. In order to determine the frequency of the use of vitamin and mineral supplements, herbs, tea, and other kinds of supplements, open-ended questions regarding the types and amounts of the supplements consumed were also included. Each food item included a fixed, commonly used portion size. The participants were asked to detail how often a given food was consumed in the previous month; the prewritten responses with regard to frequency ranged from "3 or more servings per day" to "rarely or never". The investigators informed the participants how to complete the questionnaire prior to their filling it out. To estimate vitamin D consumption from the FFQ, the vitamin D content of a serving of each food was multiplied by the frequency of its having been consumed. The vitamin D content of each food was obtained from Nutritionist Pro, software for diet analysis (2007, Axxya System, Stafford, TX), and the USDA National Nutrient Database for Standard Reference.

Sun-exposure questionnaire

A sun-exposure questionnaire was designed to ascertain the amount of sun exposure of each participant. The questions delved into the frequency of the participants' being outside more than 15 minutes, time/s of day of being outdoors, type of clothing worn when outdoors, frequency of using sunscreen (and its sun protection factor [SPF] level) when outdoors, anatomic sites protected with sunscreen, and propensity to burn/ability to tan after sun exposure. The questionnaire was designed for use in this population and has been used previously (11).

A sun-exposure index was defined using the following variables: [1] Frequency of outdoor activity for more than 15 minutes (daily = 7, 4-6 times a week = 5, 2-3 times a week = 2.5, once a week = 1, less than once a week/never = 0); [2] usual time of day for outdoor activities (between 7 and 11 a.m. = 1, between 11 a.m. and 3 p.m. = 2, between 3 and 5 p.m. = 1; [3] type of clothing used outdoors (long pants, long sleeves, closed shoes, socks, and a hat = 0 each; short sleeves, short pants or skirts, and open shoes = 1 each; bathing suit = 2); [4] frequency of sunscreen use (never = 3, fewer than 3 times per week = 2, 3-6 times per week = 1, daily = 0); [5] level of sunscreen protection (not used = 3, SPF<15 = 2, SPF 15-30 = 1, SPF>30 = 0). The ability to tan and tendency to burn was also explored: never burns/always tans (deeply pigmented) = 0, never burns/tans deeply brown or black = 1; rarely burns/tans brown = 2; burns minimally/tans easily = 3; burns moderately/tans moderately and uniformly = 4; burns easily/tans minimally = 5; burns easily/never tans = 6. This skin classification system was based on the amount of skin melanin and the responses to sun exposure and ranges from very fair (skin type I) to very dark (skin type VI) (22). Type I is highly sensitive skin that always burns and never tans; type II is very sun-sensitive skin that burns easily and tans minimally; type III is sun-sensitive skin that sometimes burns and slowly tans to light brown; type IV is minimally sun-sensitive skin that burns minimally and always tans to moderate brown; type V is sun-insensitive skin that rarely burns and tans well (Hispanics); type VI is sun-insensitive skin that never burns and is deeply pigmented (blacks). The total sun-exposure index ranged from 0 (no sun exposure, high use of clothing and sunscreen when outdoors, and never burns/always tans [deeply pigmented]) to 38 (significant sun exposure, no sunscreen and little clothing when outdoors, and burns easily/never tans).

Blood pressure

Blood pressure history and the use of antihypertensive medication were assessed as part of the main questionnaire. Blood pressure was measured using an aneroid sphygmomanometer (ReliOn; GF Health Products, Inc., Atlanta, GA) while subjects were in the sitting position with their backs supported and their legs uncrossed. Measurements were taken by a trained phlebotomist, who is also a registered nurse, in the morning; subjects had to have fasted for 12 h. We used the definition of hypertension described in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7). This report defines *hypertension* as a systolic blood pressure equal to or greater than 140 mm Hg and a diastolic blood pressure equal to or greater than 90 mm Hg (23). The committee considers a subject to be hypertensive if he/she takes any kind of antihypertensive medication. *Pre-hypertension* is defined as a systolic blood pressure of 120 to 139 mmHg or a diastolic blood pressure of 80 to 89 mmHg, while *normal blood pressure* is defined as a systolic blood pressure lower than 120 mm Hg and a diastolic blood pressure lower than 80 mm Hg. In case an individual had a reading higher than 140 mm Hg for systolic blood pressure and higher than 90 mm Hg for diastolic blood pressure and had not reported taking antihypertensive medication, the participant was asked to rest for 5 minutes, and his or her blood pressure was measured again. If it was still high, medical attention was recommended. The average of both readings was used in the analysis. A total of 46 subjects had their blood pressure taken twice, with a variation of 0.15±0.7 mm Hg for systolic blood pressure and 0.07±0.25 mm Hg for diastolic blood pressure.

Serum 25(OH)D levels

The metabolite 25(OH)D is considered to be the best marker for measuring vitamin D status since it reflects the vitamin D consumed through foods and supplements and also the endogenous production of vitamin D in the skin and its half-life is longer than the active form (7). Serum 25(OH)D levels were measured by the abovementioned local laboratory using a commercially available enzyme immunoassay kit (IDS 25-Hydroxy Vitamin D EIA kit).

The accuracy of this method was assessed by comparing it against a recognized radioimmunoassay with 180 samples selected to represent a wide range of 25(OH)D (9.3 - 151.2 nmol/L), obtaining a correlation coefficient (r) equal to 0.9. The sensitivity of 10 replicates of the zero calibrator was 5 nmol/L and the intra-assay coefficient variation was less than 9%. Recovery was assessed by adding 25(OH)D to samples prior to assay, and a mean recovery of 101% was obtained. The specificity of the antiserum at 50% binding of the zero calibrator was 100% for 25(OH)D3 and 75% for 25(OH)D2.

Controversy exists regarding the optimal levels of serum 25(OH)D in a healthy population. According to the Institute of Medicine, a 25(OH)D level greater than or equal to 20 ng/nl is considered to be optimal (6). However, some experts believe the optimal level to be greater than or equal to 30 ng/ml, with lower levels considered to be insufficient (24). Therefore, for this analysis, vitamin D status was classified as *optimal* if 25(OH)D levels were greater than or equal to 30 ng/ml and *not optimal* if 25(OH)D levels were less than 30 ng/ml.

Statistical analysis

Descriptive statistics were used to describe the study population; continuous variables were described using average and standard deviation, and categorical variables were described using frequencies and percents. The sample was stratified by hypertension group (according to the JNC 7 definition) and by vitamin D status, as defined previously. Subjects taking antihypertensive medication were not included in the analysis. Vitamin D status and blood pressure were also described by gender, age group, and BMI. Comparisons between groups were performed using ANOVA and Bonferroni post-hoc analysis for continuous variables and a chi-square test for categorical variables. Polytomous logistic regression (adjusted for age, sex, and BMI as well as for total vitamin D consumption and according to the sun exposure index) was performed to assess the association between vitamin D status and blood pressure classifications. Statistical significance was set at $p<0.05$, and all statistical analyses were performed using SAS statistical software (version 9.1; SAS Institute Inc., Cary, NC).

Results

Though 302 individuals participated in the study, 82 (27%) used antihypertensive and so were excluded; in the end, 219 subjects were included in the analyses. Sociodemographic characteristics are presented in Table 1. The majority of the subjects were female, aged 21 to 50 years old, overweight or obese, and free of hypertension history. Mean blood pressure levels were considered normal; however, when subjects were individually classified by their blood pressure levels, 53% were classified as pre-hypertensive or hypertensive. Mean serum 25(OH)D levels were within levels considered non-optimal (<30 ng/ml) and 60% were classified as non-optimal vitamin D status (<30 ng/ml). Vitamin D intake from foods and supplements was very low, and the combined intakes from these two sources were also low. Regarding sun exposure, the index was 19.6, which falls about midway through the total possible range (0 to 38).

Blood pressure classification was significantly associated with gender and age group, in that those classified as hypertensive were male and in the older ages groups ($p<0.05$; Table 2). In addition, systolic blood pressure was significantly correlated with BMI ($r = 0.16$; $p<0.05$). Vitamin D status was associated with age, and those with optimal status were older ($p = 0.055$; Table 2). It was also significantly associated with total vitamin D intake and use of supplements, in that those with higher vitamin D status had higher vitamin D intake and a greater use of supplements ($p<0.05$; data not shown). Furthermore, serum 25(OH)D levels were significantly correlated with vitamin D intake from supplements ($r = 0.33$; $p<0.001$) and with total vitamin D intake ($r = 0.27$; $p<0.001$).

Table 1. Sociodemographic characteristics of the study group (n=219)

Variable	Mean ± SD / N (%)
Female	187 (85.4)
Age (years)	41.5 ± 13.9
21-50	166 (76.0)
≥51	53 (24.0)
BMI (kg/m^2)	27.4 ± 6.9
Normal	92 (42.0)
Overweight	59 (26.9)
Obese	68 (31.1)
Hypertension history	9 (4.1)
Systolic blood pressure (mm Hg)	113.2 ± 13.1
Diastolic blood pressure (mm Hg)	73.3 ± 9.7
Blood pressure classification (JNC 7)	
Normal	104 (47.5)
Pre-hypertensive	99 (45.2)
Hypertensive	16 (7.3)
Serum 25(OH)D levels (ng/ml)	29.2 ± 10.6
Optimal (≥30 ng/dl)	87 (39.7)
Non-optimal (<30 ng/dl)	132 (60.3)
Vitamin D intake from food (IU/d)	118.0 ± 107.5
Vitamin D intake from supplements (IU/d)	258.9 ± 527.0
Total vitamin D intake (IU/d)	377.0 ± 553.7
Sun exposure index	19.6 ± 6.5

SD: Standard deviation; BMI: Body mass index

Table 3 shows mean serum 25(OH)D levels, vitamin D intake, sun exposure index, and BMI (all grouped according to blood pressure classification). We found that vitamin D intake from foods was higher in hypertensives compared to that of pre-hypertensives and normotensives, although this difference did not reach a significant level ($p = 0.06$). No other differences were found between these variables and blood pressure classifications.

Table 4 shows the polytomous logistic regression between vitamin D status and blood pressure classification, both unadjusted and after adjusting for age, sex, and BMI as well as after adjusting for age, sex, BMI, total vitamin D intake, and solar exposure index. No significant associations were found between vitamin D status and blood pressure classification after adjusting for these variables. Similar results were obtained when analyses were run using the median serum 25(OH)D levels as the cut-off point (27.6 ng/ml, instead of < or ≥30 ng/ml) or when comparing quartiles of serum 25(OH)D levels (data not shown). In addition, ANOVA was used to compare systolic and diastolic blood pressure levels between quartiles of serum 25(OH)D levels, and no significant differences were observed in mean systolic or diastolic blood pressure between the 4 quartiles ($p>0.05$; data not shown).

Discussion

The present study, performed using a convenience sample of 219 participants (85.4% of whom were female and 14.6%

Table 2. Vitamin D status and blood pressure classification by gender, age group, and body mass index group

Variables		Gender			Age groups			BMI			
		Female N%	Male N%	P-value	21-50 years N%	≥51 years N%	P-value	Normal N%	Overweight N%	Obese N%	P-value
Blood pressure classification	Normal	94	10	0.046	87	17	0.036	50	24	30	0.42
		50.3	31.3		52.4	32.1		54.4	40.7	44.1	
	Pre-hypertensive	82	17		68	31		36	29	34	
		43.9	53.1		41.0	58.5		39.1	49.2	50.0	
	Hypertensive	11	5		11	5		6	6	4	
		5.9	15.6		6.6	9.4		6.5	10.2	5.9	
Vitamin D status	Optimal	72	15	0.38	60	27	0.055	35	26	26	0.73
	(≥30 ng/ml)	38.5	46.9		36.1	50.9		38.0	44.1	38.2	
	Non-optimal	115	17		106	26		57	33	42	
	(<30 ng/ml)	61.5	53.1		63.9	49.1		62.0	55.9	61.8	

BMI: Body mass index

Table 3. Mean serum 25(OH)D levels, vitamin D intake, sun exposure index, and BMI (grouped according to blood pressure classification)

Variable	Normal Mean	SD	Pre-hypertensive Mean	SD	Hypertensive Mean	SD	P-value*
Serum 25(OH)D (ng/ml)	28.7	10.4	29.8	11.4	28.3	5.8	0.76
Vitamin D intake from food (IU/d)	112.0	103.6	115.1	108.6	171.3	116.1	0.06
Vitamin D intake from supplements (IU/d)	231.2	460.1	306.1	621.7	156.5	219.7	0.38
Total vitamin D intake (IU/d)	343.2	485.8	421.2	651.6	327.8	248.9	0.55
Sun exposure index	19.3	6.1	20.1	6.9	18.9	6.9	0.42
Body mass index (kg/m^2)	26.7	7.0	28.0	7.0	27.6	6.2	0.35

*No significant differences in these variables between blood pressure classifications (as determined by ANOVA) (p>0.05); SD: Standard deviation

Table 4. Polytomous logistic regression between vitamin D status and blood pressure classification

Variable	Pre-hypertension OR (95% CI)	Hypertension OR (95% CI)
Vitamin D status (unadjusted)		
Optimal (≥30 ng/ml)	Ref. 1.0	Ref. 1.0
Non-optimal (<30 ng/ml)	0.81 (0.46, 1.43)	1.00 (0.34, 2.97)
Vitamin D status (adjusted by age, sex, and BMI)		
Optimal (≥30 ng/ml)	Ref. 1.0	Ref. 1.0
Non-optimal (<30 ng/ml)	0.92 (0.51, 1.64)	1.24 (0.40, 3.85)
Vitamin D status (adjusted by age, sex, BMI, total vitamin D intake, and sun exposure)		
Optimal (≥30 ng/ml)	Ref. 1.0	Ref. 1.0
Non-optimal (<30 ng/ml)	0.88 (0.49, 1.60)	1.11 (0.35, 3.51)

OR: Odds ratio; CI: Confidence interval; BMI: Body mass index

of whom were male) who went to a local laboratory with a physician's order to measure their serum 25(OH)D levels, showed that blood pressure was not associated with vitamin D status in the members of this sample. We found, however, that blood pressure was associated with gender and age and that vitamin D status was significantly associated with age, total vitamin D intake, and the use of supplements.

Although this particular study found no relationship between vitamin D status and blood pressure classification, others have. Several studies have demonstrated that relatively higher serum 25(OH)D levels result in lower average blood pressure, reducing hypertension prevalence (5, 25). Furthermore, results from NHANES III in 12,644 people aged 20 years and older showed that systolic blood pressure was 3.0 mm Hg lower (p<0.001) and diastolic blood pressure was 1.6 mm Hg lower (p<0.05) for participants in the highest quintile of vitamin D status (25(OH)D ≥ 85.7 nmol/L) compared with that of participants in the lowest quintile of vitamin D status (25(OH)D ≤ 40.4 nmol/L), adjusting for age, sex, ethnicity, and physical activity (5). A prospective study of 51,529 US male health professionals and 121,700 female nurses showed that individuals with a vitamin D deficiency had 3.2-times higher risk of hypertension compared with individuals whose vitamin D levels were optimal (25). Although these 2 studies measured serum 25(OH)D levels by an enzyme immunoassay method, similar to our study, the data reported from NHANES are based on a representative sample of the US, and the data from the health professionals study are based on an ongoing prospective cohort study. However, similar to our results, there are other studies in which this relationship has not been found. A study conducted in the US with 559 women aged 24 to 44 years found no association between vitamin D status and current blood pressure (26). Also, a study in the Netherlands in 1,205 participants aged 65 years found that blood pressure was inversely associated with vitamin D levels (27). The lack of association between blood pressure classification and vitamin D status in the present study may be related to the small sample size and to the nature of the study, in which only subjects with a medical order for 25(OH)D levels were included.

Our results show that mean vitamin D intake from food was very low and reached only 20% of the level recommended by the US Institute of Medicine, which is 600 IU/d (6). When vitamin D intake from supplements was added to total vitamin D intake, the resulting total vitamin D intake reached 68.3% of the recommended level. Vitamin D intake (from foods, from supplements, or total vitamin D intake) was not associated with blood pressure. However, the aforementioned prospective study (of male health professionals and female nurses) reported that they found a significant inverse association between vitamin D intake and incidence of hypertension (25). A larger and representative Puerto Rican sample may show different results.

Among the results of our study was the fact that the average sun exposure index of the population studied was 19.6; because the index ranged from 0 to 38, this figure would seem to indicate that the members of the study population experienced an average level of sun exposure. This index was not significantly associated with blood pressure classification. However, the aforementioned NHANES study found that vitamin D status was inversely proportional to blood pressure levels when taking into account the increased levels of vitamin D that are derived from healthy levels of sun exposure (5). This effect can be attributed to the release of nitric oxide and S-nitrosothiol in the skin that occurs with sun exposure, which release then leads to the increase of plasma nitrose compounds. This increase in turn decreases blood pressure (28). Further studies, using direct methods for measuring sun exposure, are needed to confirm these results.

Although we did not find that hypertensive subjects had significantly higher BMIs compared to pre-hypertensives and normotensives, we found that systolic blood pressure was significantly correlated with BMI. This is important because a high BMI is a predictor not only of higher blood pressure but also of lower 25(OH)D levels (29). Indeed, several studies have found lower serum 25(OH)D levels in obese individuals compared to what has been found in people who are not obese, which can be explained by the fact that adipose tissue stores vitamin D, making it less bioavailable (30). In addition, it has also been found that overweight and obese people are more sedentary and participate in fewer outdoor, physical activities, meaning that they have less sun exposure, which is the major source of vitamin D (31). In the present study, physical activity was not considered.

This study has several limitations, including study design, which was cross-sectional; therefore, the design may have influenced the outcome. The population of hypertensive patients was small, and in general the sample size was limited; a larger sample size may show significant associations between blood pressure and vitamin D status. Also, the way in which blood pressure measurements were performed could have introduced some bias in the study. Because the data were gathered from individuals who were visiting a local laboratory in order to have their 25(OH)D levels checked, the sample population is not representative. The questionnaires were given to the participants and details of vitamin D intake, sunlight exposure, as well as weight and height were self-reported, which could lead to possible errors. Questions on physical activity were not included, nor were those relating to family history of hypertension, smoking status, menopausal status (in women), or the intake of other important nutrients (e.g., calcium and magnesium). For future studies, these factors must be taken into consideration. Also, prospective studies should be conducted to follow-up subjects before they develop hypertension. However, this study has several strengths, such as taking into account the most important variables for vitamin D and blood pressure such as age, sex, BMI, vitamin D intake, and sun exposure.

In conclusion, no significant associations between vitamin D status and high blood pressure were found in the 219 participants (recruited in northeastern Puerto Rico via convenience sampling).

Resumen

Objetivo: La hipertensión es un problema de salud pública global. La aparente asociación entre niveles de vitamina D (VitD) y presión arterial (PA) ha sido estudiada en diferentes poblaciones, pero en la población puertorriqueña. Por lo tanto, determinamos la asociación entre niveles séricos de 25(OH) D y PA en una muestra de conveniencia en PR. Métodos: Realizamos un estudio transversal en pacientes referidos a un laboratorio local para evaluar niveles séricos de 25(OH)D. Los participantes completaron un cuestionario que solicitaba la siguiente información: edad, sexo, peso, estatura, consumo de VitD, historial de exposición solar e historial de hipertensión. La PA fue tomada por un flebotomista y clasificada según el *Joint National Committee*; los niveles de VitD fueron tomados del récord y clasificados como *óptimos* (25(OH)D ≥30 ng/dl) o *no-óptimos* (<30ng/dl). Para el análisis descriptivo se utilizó promedios, desviación estándar y percentiles. Los niveles de VitD y PA fueron comparados por género, edad e índice de masa corporal (IMC) con ANOVA ó chi cuadrado. La asociación entre niveles de VitD y PA se hizo con regresión logística politomial. Resultados: El análisis incluyó a 219 individuos; la mayoría eran mujeres de 21-50 años con sobrepeso/obesidad; 53% fueron pre ó hipertensos, 60% tenían niveles no óptimos de VitD y el índice de exposición solar fue 19.6. No se encontró asociación significativa entre los niveles de VitD y la PA luego de

ajustarse por edad, sexo, IMC, consumo de VitD y exposición solar. Conclusión: En esta muestra no se encontró asociación entre VitD y PA. Más estudios deben ser realizados para determinar si esta relación realmente existe en la población puertorriqueña.

References

1. Center for Disease Control (CDC). Surgeon General's Reports - 2004 - Coronary Heart Disease and Stroke - Smoking & Tobacco Use. Available at: Url: http://www.cdc.gov/. Accessed: February 25, 2010.
2. Martini LA, Wood RJ. Vitamin D and blood pressure connection: update on epidemiologic, clinical, and mechanistic evidence. Nutr Rev 2008;66:291-7.
3. Puerto Rico Department of Health. Statistics of hypertension in Puerto Rico. Available at: Url: http://www.salud.gov.pr/Pages/default.aspx. Accessed: February 25, 2010.
4. Mosekilde L. Vitamin D and the elderly. Clin Endocrinol (Oxf) 2005;62:265-81.
5. Scragg R, Sowers M, Bell C. Serum 25-hydroxyvitamin D, ethnicity, and blood pressure in the Third National Health and Nutrition Examination Survey. Am J Hypertens 2007;20:713-9.
6. Institute of Medicine (IOM). Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: The National Academy Press, 2011.
7. Jones G. Pharmacokinetics of vitamin D toxicity. Am J Clin Nutr 2008;88:582S-6S.
8. Bandeira F, Griz L, Dreyer P, Eufrazino C, Bandeira C, Freese E. Vitamin D deficiency: A global perspective. Arq Bras Endocrinol Metabol 2006;50:640-6.
9. Scragg R, Sowers M, Bell C, Third National Health and Nutrition Examination Survey. Serum 25-hydroxyvitamin D, diabetes, and ethnicity in the Third National Health and Nutrition Examination Survey. Diabetes Care 2004;27:2813-8.
10. Araujo AB, Travison TG, Esche GR, Holick MF, Chen TC, McKinlay JB. Serum 25-hydroxyvitamin D and bone mineral density among Hispanic men. Osteoporos Int 2009;20:245-55.
11. Palacios C, Gil K, Perez CM, Joshipura K. Determinants of Vitamin D Status among Overweight and Obese Puerto Rican Adults. Ann Nutr Metab 2012;60:35-43.
12. Pittas AG, Chung M, Trikalinos T, et al. Systematic review: vitamin d and cardiometabolic outcomes. Ann Intern Med 2010;152:307-14.
13. Muscogiuri G, Sorice GP, Prioletta A, et al. 25-Hydroxyvitamin D Concentration Correlates With Insulin-Sensitivity and BMI in Obesity. Obesity (Silver Spring) 2010;18:1906-10.
14. Pittas AG, Lau J, Hu FB, Dawson-Hughes B. The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis. J Clin Endocrinol Metab 2007;92:2017-29.
15. Shea MK, Booth SL, Massaro JM, et al. Vitamin K and vitamin D status: associations with inflammatory markers in the Framingham Offspring Study. Am J Epidemiol 2008;167:313-20.
16. Patel S, Farragher T, Berry J, Bunn D, Silman A, Symmons D. Association between serum vitamin D metabolite levels and disease activity in patients with early inflammatory polyarthritis. Arthritis Rheum 2007;56:2143-9.
17. Wang L, Manson JE, Song Y, Sesso HD. Systematic review: Vitamin D and calcium supplementation in prevention of cardiovascular events. Ann Intern Med 2010;152:315-23.
18. Lee DM, Rutter MK, O'Neill TW, et al. Vitamin D, parathyroid hormone and the metabolic syndrome in middle-aged and older European men. Eur J Endocrinol 2009;161:947-54.
19. van den Berg H. Bioavailability of vitamin D. Eur J Clin Nutr 1997;51 Suppl 1:S76-9.
20. Sigmund CD. Regulation of renin expression and blood pressure by vitamin D(3). J Clin Invest 2002;110:155-6.
21. World Health Organization (WHO). Obesity: preventing and managing the global epidemic. Geneva: WHO, 2000. Technical Report Series, No 894.]
22. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 1988;124:869-71.
23. U.S. Department Of Health And Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7). 2004. NIH Publication No. 04-5230.]
24. Holick MF. Vitamin D status: measurement, interpretation, and clinical application. Ann Epidemiol 2009;19:73-8.
25. Forman JP, Giovannucci E, Holmes MD, et al. Plasma 25-hydroxyvitamin D levels and risk of incident hypertension. Hypertension 2007;49:1063-9.
26. Griffin FC, Gadegbeku CA, Sowers MR. Vitamin D and subsequent systolic hypertension among women. Am J Hypertens 2011;24:316-21.
27. Snijder MB, Lips P, Seidell JC, et al. Vitamin D status and parathyroid hormone levels in relation to blood pressure: a population-based study in older men and women. J Intern Med 2007;261:558-65.
28. Oplander C, Volkmar CM, Paunel-Gorgulu A, et al. Whole body UVA irradiation lowers systemic blood pressure by release of nitric oxide from intracutaneous photolabile nitric oxide derivates. Circ Res 2009;105:1031-40.
29. Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr 2000;72:690-3.
30. Young KA, Engelman CD, Langefeld CD, et al. Association of plasma vitamin D levels with adiposity in Hispanic and African Americans. J Clin Endocrinol Metab 2009;94:3306-13.
31. Salamone LM, Dallal GE, Zantos D, Makrauer F, Dawson-Hughes B. Contributions of vitamin D intake and seasonal sunlight exposure to plasma 25-hydroxyvitamin D concentration in elderly women. Am J Clin Nutr 1994;59:80-6.