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ORIGINAL ARTICLE

The Status of Vitamin D in Obese Adults in Southern Morocco: a Cross-Sectional Study

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SUMMARY

Background: **Vitamin D is a fat-soluble vitamin found in two forms, sourced either from plants (D2) or animals (D3). Numerous epidemiological studies worldwide have highlighted its deficiency across diverse populations in various countries. When coupled with obesity, this deficiency becomes a significant global health concern. Our study aimed to evaluate the vitamin D levels among obese individuals in Southern Morocco.**
Methods: **This is a retrospective, cross-sectional descriptive study on the vitamin D status in obese subjects. This study was conducted at the "Health Universe" Diet Center in Agadir, Morocco. The measurement method involved using a Tanita® wall-mounted metal stadiometer to determine height and a Tanita® BC 418 MA segmental body composition analyzer to determine weight. The serum level of 25-hydroxyvitamin D was determined by electrochemiluminescence (ECLIA) using the Elecsys® and Cobas e411®.**
Results: **The sample of our study, consisting of 1,210 individuals, is composed of 73.5% (n = 889) females and 26.5% (n = 321) males. The mean age of the entire sample is 42.3 ± 13.1 years (ranging from 18 to 86 years). The mean BMI is 37 ± 5.69 kg/m², with a higher value in females (37.4 ± 5.85 kg/m²) compared to males (35.7 ± 5.03 kg/m²), including 42.8% moderate obesity, 34.2% severe obesity, and 23% morbid obesity. The mean serum vitamin D level in our sample is 15.7 ± 7.67 ng/mL. This level is 14.5 ± 7.42 ng/mL for females and 19.2 ± 7.31 ng/mL for males. However, only 5.3% of the subjects have an adequate serum vitamin D level, while 18% have an insufficiency, 52.5% have a moderate deficiency, and 24.2% have a severe deficiency. An inverse trend was noted for BMI, which shows a very significant inverse correlation with serum vitamin D concentration ($r = -0.18$ and $p < 0.01$).**
Conclusions: **Our results support the hypothesis that obesity is inversely associated with low vitamin D levels. Lifestyle improvement should be considered as the primary treatment option, aiming to enhance the dysmetabolic state associated with obesity and vitamin D deficiency.**
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KEYWORDS

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INTRODUCTION

Vitamin D, or calciferol, is a fat-soluble vitamin. It exists in two forms depending on its source: vitamin D2 (ergocalciferol) of plant origin and vitamin D3 (chole-

calciferol) of animal origin. This vitamin is obtained either through diet or medical supplementation. It is also synthesized in the skin following exposure to sunlight, especially UVB rays, and then stored in the liver and adipose tissue [1,2].
Although the classic role of vitamin D has been known for a long time, its biological potential has expanded due to the expression of its receptor, which is related to a nuclear factor (VDR responsive element) controlling nearly 300 genes in the body. Vitamin D is now considered a true "pseudo-hormone" with multiple functions beyond its primary role in bone metabolism and its determining role in the regulation of phosphocalcic homeostasis [3]. Several epidemiological studies worldwide have shown vitamin D deficiency in various populations in many countries [4,5]. Indeed, vitamin D deficiency is often associated with chronic pathologies such as diabetes, hypertension, obesity, cancer, cardiovascular diseases, and autoimmune diseases, beyond musculoskeletal pathologies [3,6-11]. In association with obesity, vitamin D deficiency constitutes a health problem globally.
Although studies on this association have interested diverse populations, including Europeans, Americans, or Asians, no study has explored this relationship in North African populations, particularly the Moroccan population.
The objective of our study was to assess the vitamin D status in obese subjects in Southern Morocco, examining its possible correlation with certain anthropological parameters such as age, gender, waist circumference, body fat percentage, visceral fat, and body mass index (BMI) of these subjects.

MATERIALS AND METHODS

Study design and data collection

This is a retrospective, cross-sectional descriptive study on the vitamin D status in obese subjects who met the following inclusion criteria: over 18 years old, absence of chronic pathologies of renal or hepatic insufficiency, absence of parathyroid pathology, and absence of vitamin D supplementation. This study was conducted at the "Health Universe" Diet Center in Agadir, Morocco, over a period of 4 years from 27/03/2012 to 30/03/2016. Written and signed consent from patients was obtained before their inclusion in the study.

Measurement of body parameters

Body parameters, such as weight, BMI (body mass index), waist circumference, and body fat, were measured at the "Health Universe " Diet Center in Agadir, Morocco. The measurement method involved using a Tanita® wall-mounted metal stadiometer to determine height (H in cm), a tape measure to measure waist circumference (WC in cm), and a Tanita® BC 418 MA segmental body composition analyzer to determine weight (W in kg) as well as body composition parameters such as fat mass (FM), lean mass (LM), body fat percentage (BF%), visceral fat (VF), and body mass index (BMI).
The categorization of patients' body weight was performed based on the body mass index (BMI), following the criteria established by the World Health Organization (WHO) (Table 1).

Biological measurement of vitamin D

The serum level of 25-hydroxyvitamin D was determined by electrochemiluminescence (ECLIA) using the Elecsys®/Cobas e411® vitamin D total III system. The vitamin D status of patients was established in accordance with the recommendations of the American Society of Endocrinology (Table 2).

Statistical analysis

The obtained data are presented as mean ± standard deviation for quantitative variables and as percentages for qualitative variables.
Statistical analysis was conducted using jamovi 2.3.21. Pearson's correlation test was employed to assess associations between serum vitamin D concentrations and anthropometric parameters, including BMI, WC, VF, and BF%.
Group comparisons were performed by using Student's *t*-tests for unpaired series or ANOVA. A p-value < 0.05 was considered statistically significant.
Linear regression was utilized to identify the influence of each anthropometric variable (independent variables) on vitamin D status (dependent variable).
Multiple regression was employed to explore the impact of independent variables on the dependent variable.

RESULTS

Anthropometric parameters

The sample in our study, consisting of 1,210 individuals, is composed of 73.5% (n = 889) females and 26.5% (n = 321) males. The mean age of the entire sample is 42.3 ± 13.1 years (ranging from 18 to 86 years). Upon separate analysis, the mean age is 42.1 ± 13.4 years for females and 42.8 ± 12.5 years for males.
The average weight of the patients is 97.6 ± 16.6 kg, but this parameter appears significantly ($p < 0.002$) higher in males (106 ± 17.4 kg) compared to females (94.5 ± 15.1 kg), with a 95% CI = 2.2607; 10.2534.
Subjects in our study have an average height of 163 ± 8.92 cm, with a significant difference ($p < 0.0001$) related to gender. The average height is 159 ± 6.42 cm for females and 173 ± 7.14 cm for males, which is significantly higher in males, with a 95% CI = 0.115; 0.139. Regarding the classification of patients based on their body parameters, the mean BMI is 37 ± 5.69 kg/m², with a higher value in females (37.4 ± 5.85 kg/m²) compared to males (35.7 ± 5.03 kg/m²).
In the sample under study, the average prevalence rates of class I obesity are 42.8%. For class II and III obesity, these rates average at 34.2% and 23%, respectively,

Table 1. Classification of overweight and obesity by BMI [12].

Category	BMI (in kg/m^2)
Underweight	< 18.5
Normal weight	18.5 - 24.99
Overweight	25 - 29.99
Moderate obesity: class 1	30 - 34.99
Severe obesity: class 2	35 - 39.99
Morbid obesity: class 3	> 40

Table 2. Vitamin D status according to the American Society of Endocrinology [13].

Serum vitamin D level	Vitamin D status
30 - 100 ng/mL	Optimal threshold
< 30 ng /mL	Insufficiency
10 - 20 ng/mL	Moderate deficiency
< 10 ng/mL	Severe deficiency

with a more significant tendency observed among females (28.6%, 26%, and 18.9%, respectively) compared to males (14.2%, 8.2%, and 4.1%, respectively) (Table 3).The analysis of abdominal obesity in patients showed an average waist circumference (WC) of 116 cm, with a notable gender-related discrepancy (115 ± 12.4 cm in females and 119 ± 12.5 cm in males). However, the body fat percentage (BF%), averaging 43.1 ± 7.22%, is significantly higher in females compared to males (46.27 ± 4.28% and 33.5 ± 4.56%, respectively). The visceral fat (VF) parameter has an average value of 13.4 ± 4.71 kg, but it is significantly higher in males compared to females (17.1 ± 5.11 kg and 12.1 ± 3.75 kg, respectively) ($p < 0.0001$).

Vitamin D status

The mean serum vitamin D level in our sample is 15.7 ± 7.67 ng/mL. This level is 14.5 ± 7.42 ng/mL for females and 19.2 ± 7.31 ng/mL for males. However, only 5.3% of the subjects have an adequate serum vitamin D level, while 18.00% have an insufficiency, 52.5% have a moderate deficiency, and 24.2% have a severe deficiency. The levels of insufficiency appear to be related with gender. Indeed, adequate vitamin D levels are present in 4.61% of the females and 7.16% of the males, while insufficiency is 32.4% and 12.82% in males and females, respectively. Vitamin D deficiency affects 51.09% of males and 52.98% of females, but severe deficiency is observed in 29.59% of the females and only 9.35% of the males (Table 4).

Relationship between vitamin D and anthropometric parameters

The cross-analysis of vitamin D status and the Anthropometric parameters of patients indicates that age does not exhibit a correlation for either men or women, whereas waist circumference (WC) shows a weak but significant negative correlation across the entire sample (Pearson coefficient, $r = -0.062$ and $p = 0.032$). However, a highly significant impact was observed for the gender variable on serum vitamin D concentration. The average serum vitamin D level is significantly higher in men than in women ($p < 0.0001$). However, when comparing each modality of vitamin D status to its counterpart, only the deficiency modality is significantly more prevalent in women than in men ($p < 0.004$). An inverse trend was noted for BMI, which shows a significant inverse correlation with serum vitamin D concentration (Pearson's coefficient, $r = -0.18$ and $p < 0.01$).
Statistical analysis revealed a significant inverse correlation between vitamin D status and body fat ($r = -0.273$ and $p < 0.001$) in the general population. This correlation is also negative and inverse when taking the female gender as the reference modality ($r = -0.176$ and $p < 0.001$), as well as between the latter and visceral fat. However, no correlation was noticed with the amount of visceral fat ($r = -0.053$ and $p = 0.067$).
In our patient cohort, 20% had type 2 diabetes mellitus. Among diabetic women, the average serum vitamin D level was 13.96 ± 6.62 ng/mL, compared to 15.79 ± 6.89 ng/mL in non-diabetic women, showing a statistically significant difference ($p = 0.012$). Among diabetic men, the mean vitamin D level was 18.77 ± 7.15 ng/mL, whereas it was 20.87 ± 6.06 ng/mL in non-diabetic men. The difference observed between the average vitamin D levels in diabetic and non-diabetic men was also statistically significant ($p = 0.028$).

DISCUSSION

Recognizing the skeletal and extra-skeletal impacts of vitamin D, especially its reverse relationship with obesity, emphasizes the importance of maintaining sufficient levels of vitamin D to reduce adiposity.
In our study, the prevalence of severe vitamin D deficiency among obese subjects was 24.2%. These findings align with numerous studies in the literature that have delved into vitamin D deficiency and its associated comorbidities [3,4]. Notably, vitamin D deficiency in our study is more pronounced among adult women than adult men ($p < 0.001$). However, some studies conducted in Nordic countries [7], exploring the correlation between gender and vitamin D deficiency in obese subjects, have reported results contrary to ours. This discrepancy may be due to the substantial sunlight exposure in our country, enabling the attainment of appropriate serum vitamin D levels. UV rays from sunlight, indeed, stimulate the synthesis of this prohormone through its precursor in the skin [8,9].

Table 3. Obesity class frequencies.

Class of obesity	Gender	Counts	% of Total	% Cumulative
Obesity I	female	346	28.6 %	28.6 %
	male	172	14.2 %	42.8 %
Obesity II	female	314	26.0 %	68.8 %
	male	99	8.2 %	77.0 %
Obesity III	female	229	18.9 %	95.9 %
	male	50	4.1 %	100.0 %

Table 4. The distribution of vitamin D status in the sample for both genders.

Status of vitamin D	Gender	Count	% of Total	% Cumulative
Adequate status	female	41	3.4 %	3.4 %
	male	23	1.9 %	5.3 %
Insufficiency	female	114	9.4 %	14.7 %
	male	104	8.6 %	23.3 %
Moderate deficiency	female	471	38.9 %	62.2 %
	male	164	13.6 %	75.8 %
Severe deficiency	female	263	21.7 %	97.5 %
	male	30	2.5 %	100.0 %

Table 5. Correlation between vitamin D and various anthropometric parameters.

Variables	Correlation coefficient	p-value
BMI	-0.18	< 0.01
Body fat %	-0.273	< 0.001
Visceral fat (VF)	-0.053	0.067
Fat mass (FM)	-0.179	< 0.001
Waist circumference (WC)	-0.062	0.032
Waist/Hip ratio (WC/HC)	0.018	0.598

For BMI, body fat percentage, fat mass, and visceral fat, the correlation is significant at the 0.01 level. For the waist circumference parameter, the correlation is significant at the 0.05 level.
VF - visceral fat, FM - fat mass, WC - waist circumference, HW - hip circumference, BMI - body mass index.

In the southern region of Morocco, cultural and religious norms lead women to wear clothing covering their entire bodies, hindering skin exposure to sunlight. These factors might contribute to the heightened prevalence of vitamin D deficiency among obese women, despite the southern region of Morocco being characterized by a climate that offers 340 days of sunlight annually.

Indeed, despite Morocco being a sunlit country, several studies indicate that it is not an exception concerning the issue of vitamin D hypovitaminosis. Most studies conducted demonstrate that serum vitamin D levels vary widely but consistently remain deficient on a national scale. Our study indicates that in the southern region of Morocco, despite significant sunlight exposure, vitamin D deficiency is more pronounced than in other regions located to the north of Morocco [14-17]. This observation can be attributed to the substantial size and diversity of our sample in terms of age and gender. Additionally, other factors such as culinary practices, high cooking temperatures, and prolonged cooking of food, which impair the bioavailability of vitamin D, along with cultural aspects specific to the southern regions of Morocco, may also contribute to the state of hypovitaminosis D [14].

Moreover, the avoidance of sunlight exposure, particularly in the southern provinces, concealing clothing, the scarcity of vitamin D-fortified foods in Morocco, and the more sedentary lifestyle of women compared to men likely contribute to the recorded vitamin D deficiency in the present study.

Regarding vitamin D hypovitaminosis and obesity, the analysis of BMI, as a tool for classifying body weight in our patients, revealed a highly significant weak negative correlation between BMI and serum vitamin D status (Pearson's coefficient, $r = -0.18$, $p < 0.01$). The results obtained align with several studies demonstrating a significant association between obesity and vitamin D deficiency [18-20]. However, some studies conducted on adult subjects have shown a limited or no association between vitamin D hypovitaminosis and obesity [14, 16].

For older subjects, studies have also demonstrated an association between obesity and vitamin D hypovitaminosis [15,17]. Regarding the relationship between vitamin D status and body fat percentage, our study revealed a significantly inverse association between these variables ($p < 0.01$). This finding is consistent with some studies confirming that increased body fat mass is linked to a low serum vitamin D level; for every increase of 10 units of serum 25(OH)D, there was a decrease of 0.03 units in android fat [17]. Conversely, high serum vitamin D levels are associated with a decrease in body weight gain in older women [14].

Regarding the relationship between vitamin D status and visceral fat, our study did not reveal any correlation. The correlation observed in our study between waist circumference (WC) and serum vitamin D concentration has been described by other authors [21]. This relationship could be explained by the fact that waist circumference expresses a significant amount of abdominal fat in obese individuals.

Through our study, vitamin D deficiency would be considered among the risk factors for obesity. Indeed, the pathophysiological mechanisms invoked to illustrate this association are manifold and still not fully elucidated. Vitamin D, being a fat-soluble hormone, could be sequestered by excess body fat in obese individuals, leading to a decrease in its bioavailability [21,22]. Its deficiency may promote the increase of adipose tissue by stimulating the synthesis of parathyroid hormone, which in turn increases calcium intake into adipocytes. This can stimulate lipogenesis and inhibit lipolysis [23]. Depletion of vitamin D reserves could also play a role by leading to excessive differentiation of preadipocytes into adipocytes. Among other mechanisms, one can mention the high expression of the vitamin D receptor in adipose tissue, suggesting the role of vitamin D in the pathogenesis of metabolic syndrome [24].

Our results also highlighted a positive association between type 2 diabetes and hypovitaminosis D in obese subjects, particularly in women. In this context, links between hypovitaminosis D and type 2 diabetes have been extensively reported in obese individuals [25]. Molecular studies have provided insights into certain aspects of this association. According to Abdel-Rehim et al.'s study [26], the anti-diabetic effect of vitamin D3 can be mediated through various mechanisms, including induction of insulin secretion by increasing intracellular calcium concentration, activation of β-cell-dependent endopeptidase facilitating the conversion of proinsulin to insulin, or improvement of insulin sensitivity through stimulation of insulin receptors and/or activation of Peroxisome proliferator-activated receptor-delta (PPAR-δ) and local pancreatic suppression of the renin-angiotensin-aldosterone system (RAAS). According to the same author, vitamin D3 can also promote the survival of β-cells by inactivating nuclear factor kappa B (NF-κB) [27].

Overall, our study has shed light on the critical role of obesity as a determining factor influencing serum vitamin D levels. The various correlations identified between BMI, fat mass, percentage of body fat, abdominal fat, and vitamin D status in our sample suggest a bidirectional association. In other words, the occurrence of vitamin D deficiency and adiposity appears to be a risk factor for the development of the other [28,29].

Furthermore, our study revealed that vitamin D deficiency represents a risk factor for the development of type 2 diabetes, acting through its influence on mechanisms related to the onset of metabolic syndrome. However, it is important to note that variables such as genetic and epigenetic factors, physical activity, and sunlight exposure could play a crucial role in confirming this association.

CONCLUSION

Our study, the first of its kind in Morocco, has elucidated the relationship between serum vitamin D levels and anthropometric parameters, such as age, BMI, body fat percentage, and waist circumference, among patients in the southern region of Morocco. There is a significant inverse correlation between obesity and serum vitamin D levels, even with the constant sunshine in the region. However, despite these sunny conditions, hypovitaminosis D appears to be prevalent, especially among women. These results support the hypothesis that obesity, BMI, and body fat are inversely associated with low vitamin D levels.

The causality of this association remains uncertain. Lifestyle improvement should be considered as the primary treatment option, aiming to enhance the dysmetabolic state associated with obesity and vitamin D deficiency.

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Declaration of Interest:

The authors have no conflicts of interest to declare.

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