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Spectrum of Vitamin D Deficiency across GFR Levels in a Senegalese Cohort

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Abstract

The optimal serum concentration of vitamin D for bone and mineral homeostasis remains debated and few data are available in sub-Saharan Africa. We conducted a cross-sectional study between February 2022 and April 2025 at the Ouakam Military Hospital biochemistry laboratory to assess the prevalence of vitamin D deficiency and its relationship with renal function in adults referred for vitamin D testing at a tertiary hospital laboratory in Dakar, Senegal. All patients aged ≥ 18 years undergoing serum vitamin D testing were included. Vitamin D deficiency was defined as 25(OH)-vitamin D < 12 ng/mL, insufficiency as 12 - 19 ng/mL and sufficiency as ≥20 ng/ml. A total of 1192 patients were enrolled (median age 44.0 [31.0 - 62.0] years; M:F ratio 0.8). The prevalence of vitamin D deficiency and insufficiency was 15.44% and 22.99%, respectively. Deficient patients exhibited significantly lower serum calcium ($p < 0.001$). Both pathological fractures ($p = 0.54$) and kidney dysfunction ($p = 0.07$) were more frequent in deficient individuals. Serum 25(OH)-vitamin D correlated positively albeit weakly with eGFR ($r = 0.10$; $p < 0.001$). More than half (51.2%) of patients with stage 4 - 5 kidney dysfunction had vitamin D deficiency or insufficiency compared with 34.8% of those with preserved renal function. No significant seasonal variation was observed although higher mean levels coincided with sunnier months. Our findings highlight a substantial burden of hypovitaminosis D in Senegal and its association with impaired renal function.

Keywords

Vitamin D Deficiency, Kidney Dysfunction, Senegal

1. Introduction

Vitamin D is a crucial hormone with several biological functions in humans. The optimal serum vitamin D concentration to ensure a well-balanced mineral bone balance is controversial. Several international recommendations are issued with different definitions thresholds depending on the clinical context and biological targets. It is estimated that over a billion people worldwide are vitamin D deficient or insufficient [1]. Usually around 90% of vitamin D is produced by sunshine exposure of skin and the remainder comes from the diet [2]. The duration of daily sun exposure required to achieve an adequate concentration of vitamin D varies depending on skin type and is longer in individuals with darker skin [3]. Vitamin D plays a major role in the homeostasis of calcium and phosphate metabolism [4]. It exists primarily in two forms: 25-hydroxyvitamin D, which is the circulating storage form and is well correlated with cutaneous production and dietary intake and 1,25-dihydroxyvitamin D, the active form responsible of the biological effects of vitamin D [5]. The kidney plays an essential role in the metabolism of vitamin D through its tubular 1α-hydroxylase activity. Chronic kidney dysfunction leads to progressive loss of this 1α-hydroxylase activity, combined with other risk factors such as inflammation, low sun exposure, cutaneous abnormalities and reduced dietary intake that contribute to vitamin D deficiency [6]. Prolonged vitamin D deficiency increases susceptibility to infections and osteomalacia in children and risk of osteoporosis in adults [7]. However, few data are available on the epidemiology of vitamin D deficiency in sub-Saharan Africa. This study was therefore conducted with the objective of determining the prevalence of vitamin D deficiency and its association with kidney function in adults referred for laboratory testing in Senegal.

2. Patients and Methods

We conducted a monocentric cross-sectional study conducted between February 2022 and April 2025 at the Ouakam military hospital (Dakar, Senegal). We included all patients aged 18 years or older who underwent vitamin D testing during this period for different reasons. We excluded repeated measurements from the same patient and samples with missing creatinine values. During the study period, a total of 1964 vitamin D measurements were recorded. After exclusion of repeated measurements (n = 772) a final sample of 1192 unique patients was included in the analysis. For each patient, socio-demographic and clinico-biological data were collected from medical and laboratory records. Vitamin D in blood sample was measured by competitive chemiluminescent immunoassay method with an Abbott Architect ci8200® automaton (Abbott Diagnostics, Lake Forest, IL, USA).

We used the chronic kidney disease-Epidemiology Collaboration (CKD-EPI) 2021 formula to estimate glomerular filtration rate (eGFR) [8]. Kidney dysfunction was classified by eGFR category using the KDIGO chronic kidney disease classification [9]. For binary analyses, kidney dysfunction was defined as an eGFR

< 60 mL/min/1.73m^2. Vitamin D sufficiency was defined by a level of 25(OH)-vitamin D (25(OH)D) ≥ 20 ng/ml, vitamin D insufficiency was defined by a level between [12 - 20[ng/ml and vitamin D deficiency by a level < 12 ng/ml [10]. Pathological bone fracture was defined as a fracture that occurred spontaneously or following of a low-energy trauma [11]. Correlations between participants' serum vitamin D levels and UV sunlight exposition was assessed using data on sunshine intensity during the different months of year [12].

Because most distributions were skewed, continuous data are presented as medians with interquartile ranges (IQR) and groups were compared using the Kruskal–Wallis test. Categorical variables are presented as counts and percentages and were compared using Pearson's chi-square test. Correlations between serum 25(OH)D and eGFR or age were assessed using Spearman's rank coefficient because of the non-normal distribution of these variables. A p-value < 0.05 was considered statistically significant.

Data were entered in Excel software (v16.78) and analyzed with SPSS software (v23.0).

3. Results

A total of 1192 patients were included in this study. The median age was 44.0 [31.0 - 62.0] years with a male-to-female ratio (M:F) of 0.80. One hundred and eighty-four (15.44%) patients had vitamin D deficiency and 274 (22.99%) had vitamin D insufficiency (Table 1). As shown in Figure 1, serum 25(OH)-vitamin

Table 1. Characteristics of patients according to their vitamin D status.

	N	vitamin D deficiency (n = 184)	vitamin D insufficiency (n = 274)	vitamin D normal (n = 734)	total (n = 1192)	p-value[$]
Age*, years	1192	42.5 [30.0 - 61.0]	44.0 [31.3 - 64.0]	44.0 [31.0 - 62.0]	44.0 [31.0 - 62.0]	0.389
Age group	1192					0.255
<65 years		149 (80.98)	206 (75.18)	582 (79.29)	937 (78.61)	
≥65 years		35 (19.02)	68 (24.82)	152 (20.71)	255 (21.39)	
Sex, (%)	1192					0.255
Male		92 (50.00)	109 (39.78)	328 (44.69)	529 (44.38)	
Female		92 (50.00)	165 (60.22)	406 (55.31)	663 (55.62)	
Creatinine*, mg/l	1192	10.2 [9.0 - 12.1]	10.0 [9.0 - 12.0]	10.0 [8.9 - 11.6]	10.0 [9.0 - 11.9]	0.076
Kidney dysfunction (%)	1192	46 (25.00)	68 (24.82)	141 (19.21)	255 (21.39)	0.067
Calcemia* mg/l	1191	84.0 [79.0 - 90.0]	86.0 [80.0 - 91.8]	88.0 [83.0 - 93.0]	87.0 [81.0 - 92.0]	<0.001
Parathormone* ng/l	100	109.0 [95.0 - 180.0]	104.4 [89.5 - 196.3]	89.5 [77.3 - 123.0]	99.5 [79.9 - 143.5]	0.025
Pathological fracture (%)	1192	5 (2.72)	4 (1.46)	19 (2.59)	28 (2.35)	0.539
Intake of vitamin D (%)	1192	10 (5.43)	7 (2.55)	25 (3.40)	41 (3.44)	0.251

[$]Kruskal-Wallis rank sum test, Pearson's Chi-square test; *Median [IQR].

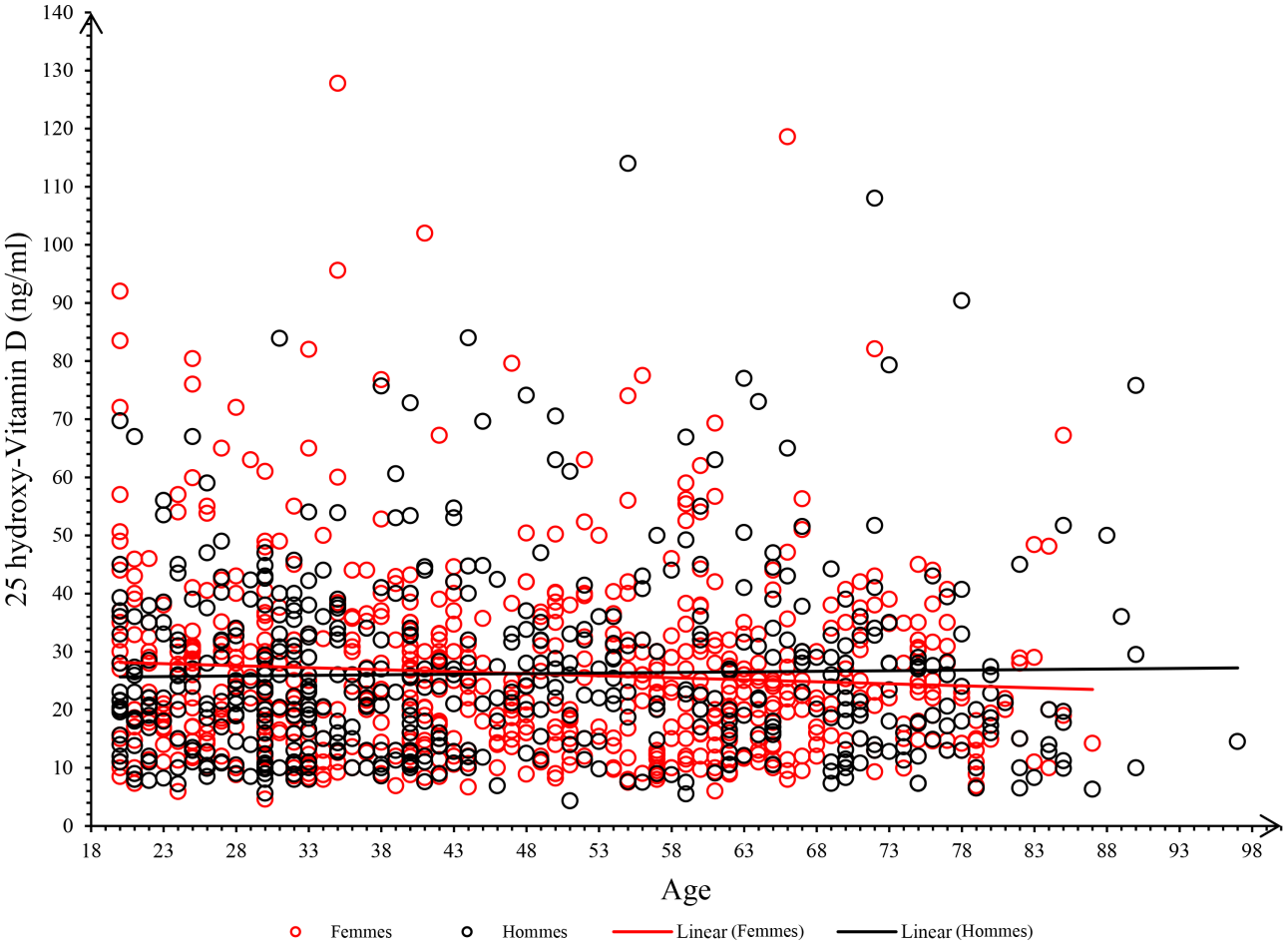

Figure 1. Correlation between vitamin D levels and age. spearman rho (ρ) = 0.08 for women and 0.02 for male.

D levels showed a very weak correlation with age, with spearman's rho values of 0.08 in women and 0.02 in male. Among patients with vitamin D deficiency, serum calcium levels were significantly lower ($p < 0.001$) compared to those with vitamin D insufficiency and those with normal vitamin D levels. The proportion of patients with pathological fractures ($p = 0.54$) and kidney dysfunction ($p = 0.07$) was higher among those with vitamin D deficiency compared to the other subgroups (Table 1). Vitamin D levels showed a weak positive correlation ($\rho = 0.10$; $p < 0.001$) with renal function (Figure 2). Overall, 51.2% of patients with severe renal dysfunction (eGFR < 30 ml/min/1.72m^2) were vitamin D deficient or insufficient, whereas this proportion was 34.8% among those with an eGFR ≥ 90ml/min (Figure 3). The mean vitamin D level throughout the year was 25.13 ng/mL, 26.68 ng/mL, 26.70 ng/mL, and 26.95 ng/mL during the first, second, third, and fourth quarters, respectively ($p = 0.854$) (Figure 4). The highest monthly mean vitamin D level was observed in April (28.47 ± 16.18 ng/mL) which also corresponds to the sunniest month of the year with an average of 9.6 hours of sunshine per day (Table 2).

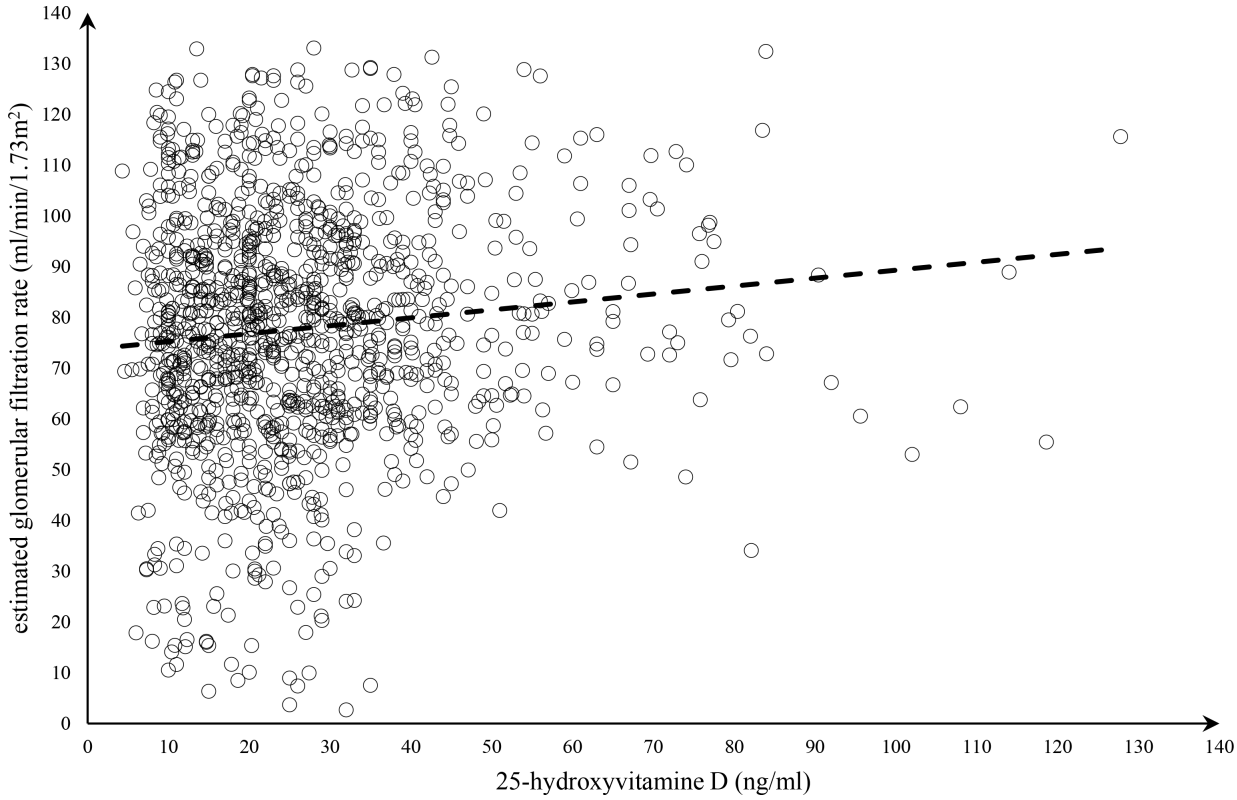

Figure 2. Correlation between vitamin D levels and kidney function. spearman rho (ρ) = 0.10 ($p < 0.001$).

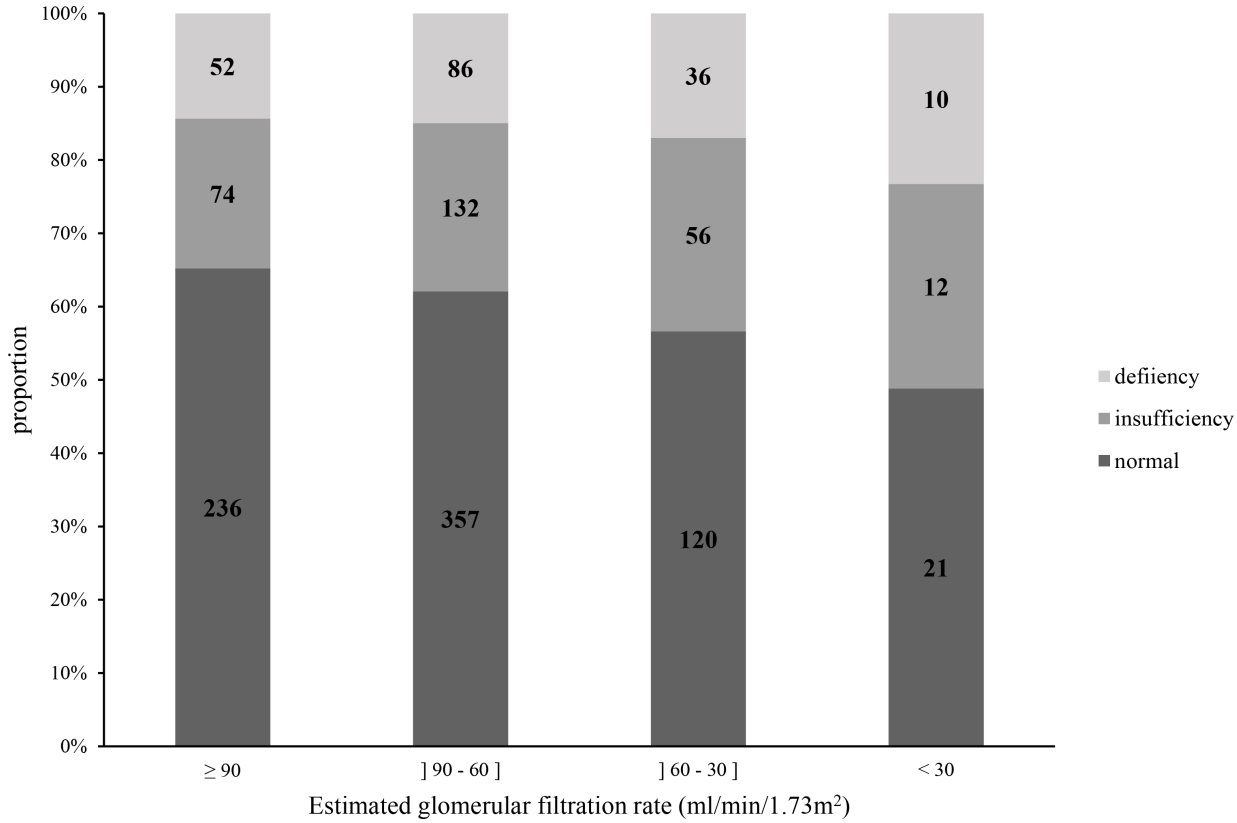

Figure 3. Vitamin D status across glomerular filtration rate categories ($p = 0.43$).

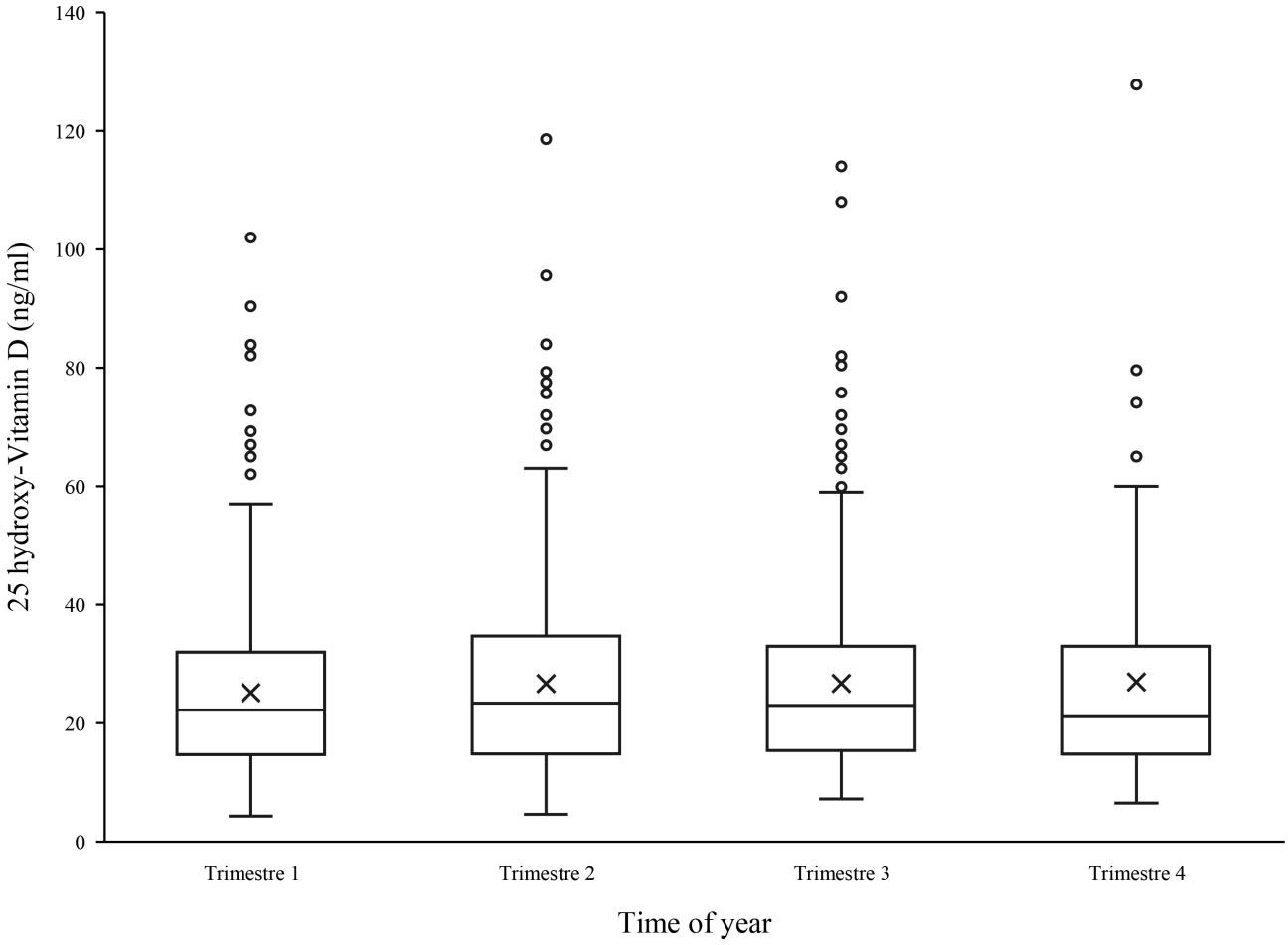

Figure 4. Variations of vitamin D levels by quarter of the year (p = 0.854).

Table 2. Average monthly level of 25-hydroxyvitamin D throughout the year (p = 0.703).

Month	Mean (ng/ml) ± standard deviation	Average sunshine rate (hours/day) [12]
January	27.19 ± 16.79	8.1
February	23.31 ± 13.56	8.4
March	25.04 ± 13.15	8.8
April	28.47 ± 16.18	9.6
May	26.14 ± 15.83	9.4
June	25.46 ± 16.01	8.5
July	27.71 ± 18.43	8.0
August	25.52 ± 17.28	7.5
September	25.74 ± 10.97	7.3
October	27.12 ± 18.83	8.0
November	25.74 ± 14.44	8.0
December	27.09 ± 15.38	8.0

4. Discussion

Little is known about the vitamin D status of the Senegalese adult population. In this cross-sectional study, we assessed the prevalence of vitamin D deficiency and its association with kidney function using data from a sample of Senegalese adults undergoing vitamin D laboratory testing. Reported prevalence of vitamin D deficiency varies globally, ranging from 5.9% in the United States [13], 7.4% in Canada [14] to 13% in Europe [15], while insufficiency is estimated at 24%, 37%, and 40%, respectively [13]-[15]. In Africa, the overall prevalence of vitamin D deficiency and insufficiency has been reported to be 18% and 34% respectively [16]. In our cohort, vitamin D deficiency and insufficiency were observed in 15.44% and 22.99% of participants, respectively. These high rates of vitamin D deficiency across continents are related to several factors including reduced cutaneous synthesis due to hyperpigmentation and/or aging, insufficient sunlight exposure and to a lesser extent inadequate dietary intake [17].

Adequate sunlight exposure is essential for optimal cutaneous vitamin D synthesis with seasonal variability demonstrated in different populations. In Slovenia, a study reported a high seasonal variation in serum vitamin D levels with deficiency being particularly pronounced during winter [18]. In China, vitamin D levels were found to be significantly higher between April and October compared to the rest of the year [19]. We observed a similar pattern in Senegal where monthly mean 25(OH)-vitamin D concentrations were higher during the second quarter corresponding to the sunniest period of the year.

In addition to adequate sunlight exposure, skin pigmentation plays an important role in vitamin D synthesis capacity. Hyperpigmentation associated with elevated melanin levels reduces the ability of skin cells to synthesize vitamin D [20] [21]. Data from Nigeria reported that albino individuals exhibited significantly higher 25(OH)-vitamin D levels compared with normally pigmented individuals [22].

More than half of the patients with severe kidney dysfunction (eGFR < 30 ml/min/1.72m^2) in our study had 25(OH)-vitamin D levels < 20 ng/ml. Similar proportions have been reported in U.S. hemodialysis populations where 57% of patients had 25(OH)-vitamin D levels < 20 ng/ml [23]. This decline in vitamin D status during kidney disease is linked to many alterations in vitamin D metabolism. While reduced sunlight exposure, cutaneous abnormalities and low food intake contribute to the deficiency, another mechanism involves urinary losses due to impaired reabsorption of the 25(OH)-vitamin D—Vitamin D Binding Protein complex in the proximal tubule [24]. This defect reduces renal hydroxylation of vitamin D, leading to decreased circulating 25(OH)-vitamin D levels [25]. Such reductions appear early in the course of kidney disease and worsen with disease progression, a trend consistently observed in our cohort.

Vitamin D deficiency in adults, particularly those with kidney dysfunction has been associated with adverse clinical outcomes including bone fragility, increased fracture risk and high cardiovascular morbidity [26]. These effects are largely mediated through disturbances in mineral metabolism with elevated parathyroid

hormone (PTH) and fibroblast growth factor-23 (FGF-23) levels driving secondary hyperparathyroidism [25]. In our cohort, this biological mechanism was reflected by significantly higher PTH levels among patients with vitamin D deficiency compared to those with normal status ($p = 0.025$).

Despite the above results, this present study has some limitations that should be acknowledged. First, the monocentric and hospital-based design introduces a risk of indication and referral bias, as included patients were selected based on clinical indications for vitamin D testing. Therefore, the findings may not be generalizable to the general population. Second, some variables that are known to influence vitamin D status such as body mass index, dietary intake and clothing habits were not available in our dataset and may restrict a more comprehensive interpretation of the determinants of vitamin D deficiency. Also, Vitamin D supplementation was not adjusted for in the analysis and may represent a potential confounder.

However, these findings support the need of assessing vitamin D status in Senegalese adults in order to detect and correct potential deficiency even in those with normal kidney function despite regularly exposed to UV sunlight.

5. Conclusion

Our study demonstrates that vitamin D deficiency and insufficiency are common among adults referred for vitamin D testing in a hospital setting, affecting nearly 40% of the study population. The burden is particularly high in patients with severe kidney dysfunction, supporting the role of renal impairment in altered vitamin D metabolism. Although seasonal trends were modest, higher concentrations during sunnier periods reinforce the importance of sunlight exposure. Given skeletal and extra-skeletal consequences of hypovitaminosis D, especially in the context of kidney disease, routine monitoring and preventive strategies including optimized sun exposure and nutritional support should be considered in Senegal and similar sub-Saharan African settings.

Ethical Consideration

This study was conducted in accordance with the principles of the Declaration of Helsinki. Individual informed consent was waived given the cross-sectional design of the study based on anonymized laboratory and hospital records. The study protocol was approved by the ethics committee of the Ouakam Military Hospital.

Authors' Contribution

Study design: S.M.S, M.N; Data collection: S.M.S, B.F; Statistical analysis: S.M.S, M.N; Data interpretation and manuscript preparation: S.M.S, M.N, I.L.S; Final revision of the manuscript: M.N, I.L.S, B.C, B.M, C.F, L.N.M.L, B.F, S.M.S.

All authors reviewed and approved the manuscript.

Data Availability Statement

The datasets used and/or analyzed during the current study available from the

corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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