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Vitamin D deficiency and its associated factors among HIV patients at Mbarara City Health Centre IV, south-western Uganda

Authors:
Jazira Tumusiime[1]
Charles N. Bagenda[1,2]
Daniel Nzaramba[1]
Bashir Ruzige[3]
Elastus Ssemwanga[4]
Frank Ssedyabane[1]
Winnie R. Muyindike[5]
Ritah Kiconco[1,6]
Simon P. Rugera[1]

Affiliations:
[1]Department of Medical Laboratory Science, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara, Uganda

[2]Uganda Institute of Allied Health and Management Sciences, Kampala, Uganda

[3]Department of Emergency Medicine, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara, Uganda

[4]Department of Medical Laboratory Technology, Faculty of Medicine, Mayanja Memorial Medical Training Institute, Mbarara, Uganda

[5]Department of Internal Medicine, Faculty of Medicine, Mbarara University of Science and Technology, Mbarara, Uganda

[6]Department of Biochemistry, School of Health Sciences, Soroti University, Soroti, Uganda

Corresponding author:
Jazira Tumusiime,
jaziratumusiime@must.ac.ug

Background: HIV is a global health challenge. Despite increased life expectancy because of antiretroviral therapy, vitamin D deficiency (VDD) remains widespread among HIV-positive individuals. Factors such as poor nutrition, limited sunlight exposure, and certain medications, contribute to high VDD rates. Despite this, the magnitude of this problem is not well documented in our setting.

Objective: The purpose of this study was to determine the prevalence and factors associated with VDD among HIV patients in south-western Uganda.

Methods: This cross-sectional study at Mbarara City Health Centre IV involved 218 randomly selected HIV patients on antiretroviral therapy. Data were collected through structured questionnaires, medical records review, and blood samples for biochemical analysis. VDD was defined as serum levels < 25 ng/mL. Levels of > 5 mg/L for C-Reactive Protein (CRP) were considered elevated. Body mass index (BMI) was categorised as < 25 kg/m^2 normal, 25–29.9 kg/m^2 overweight, and ≥ 30 kg/m^2 for obese. Statistical analysis included descriptive statistics and logistic regression to assess factors associated with VDD.

Results: The median age of the participants was 38 years (interquartile range 30–45) with most being female (163, 74.8%). Of the 218 study participants, 66 had Vitamin D levels < 25 ng/mL, giving a prevalence of VDD of 30.3% (95% CI: 24.51% – 36.73%). Being overweight, obese, and having a CRP level of > 5 mg/L, were significantly associated with VDD.

Conclusion: The study found a 30.3% prevalence of VDD among HIV-positive individuals at Mbarara City Health Centre IV. Key associated factors included higher BMI and elevated CRP levels.

What this study adds: This study highlights the significant burden of VDD among HIV-positive individuals in a Ugandan setting, with a prevalence of 30.3%. It identifies obesity and elevated CRP levels as key risk factors, emphasising the need for integrated nutritional and inflammatory monitoring in HIV care.

Keywords: vitamin D; human immunodeficiency virus; deficiency; inflammation; obesity; nutrition; Uganda; body mass index.

Introduction

HIV infection is an intercontinental health challenge affecting millions of people. According to the World Health Organization, by the end of 2022, there were 39.0 million (33.1–45.7 million) HIV-positive individuals worldwide.[1] Since the introduction of antiretroviral therapy (ART), people with HIV have a considerably greater life expectancy.[2] However, this prolonged survival has brought to the forefront a range of health-related issues, which could result from prolonged use of ART or other factors.[3] Among these health issues, vitamin D deficiency (VDD) was identified as a neglected and upcoming epidemic among people living with HIV.[4]

Vitamin D is an important component needed for many physiological processes, such as hormone regulation, bone health, and immunological function.[5] It also plays a role in calcium

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phosphate metabolism.[6] An optimal vitamin D level increases muscle strength and improves bone mineral density, lowering the possibility of falls and fractures. In HIV patients, optimal vitamin D levels are essential for maintaining a healthy immune function and improving overall health outcomes.[4]

However, VDD is a common issue worldwide, affecting different populations, including individuals living with HIV. A review article reported that the prevalence of vitamin D insufficiency is overly high within those living with HIV around the world, with approximately 70% to 85% of patients experiencing insufficient levels.[7] This high prevalence is as a result of a complex interplay of factors that could be specific to the virus and its treatment, as well as general lifestyle and environmental conditions.[8] Studies by Manion et al.,[9] Escota, Cross and Powderly,[10] and Lambert et al.[11] reported factors such as poor nutrition, limited sunlight exposure, impaired absorption of vitamin D in the gut, and increased inflammation, to be linked to vitamin D insufficiency in HIV-positive individuals. Additionally, the use of ART in HIV treatment has been affiliated with further reductions in vitamin D levels. Furthermore, certain antiretroviral medications, such as efavirenz and tenofovir, have been linked to both lower vitamin D levels and elevated parathyroid hormone levels.[12,13]

In East Africa, a study at Aga Khan University Hospital, Nairobi indicated a high deficiency of vitamin D, with a prevalence of 39%, among people living with HIV.[14] A study done in Kampala, Uganda, among HIV patients at the Infectious Disease Institute in Makerere, found a VDD prevalence of 17%.[15]

Tuberculosis also remains one of the most common opportunistic infections among people living with HIV, and HIV/tuberculosis co-infection has been associated with VDD. A meta-analysis study conducted in 2024 found that the prevalence of VDD was higher in the HIV-tuberculosis group than in the HIV group, addressing this deficiency in co-infected populations.[16] People living with HIV often face dietary challenges, stemming from factors such as side effects of medications, limited access to a balanced diet, and socioeconomic constraints.[17] This may further contribute to suboptimal intake of vitamin D through diet. Also, environmental and lifestyle factors, including geographic location, limited sun exposure, and co-infections, can exacerbate the risk of VDD in these individuals.[5]

In Uganda, south-western Uganda in particular, there is little information on the prevalence of VDD among HIV patients, yet information from other countries has indicated a high prevalence.[7] At Mbarara City Health Centre IV, vitamin D is not routinely assessed in people living with HIV, despite the fact that it has a functional ART clinic, with approximately 5000 active ART patients (verbal communication from the clinic in-charge). The clinic receives about 700 patients per week, the majority of whom are women of advanced age, making them prone to VDD. Therefore, the goal of this research is to determine the prevalence and the factors that are associated with VDD among HIV-infected patients at Mbarara City Health Centre IV, south-western Uganda.

Methods

Ethical considerations

Approval was sought from the Research Ethics Committee of Mbarara University of Science and Technology (reference number: MUST-2024-1609) before patients were involved. Clearance was obtained from the Mbarara City Town Clerk through the City Health Officer and the director of Mbarara City Health Centre IV to access the antiretroviral therapy clinic and the laboratory. Written informed consent was also obtained from the participants, and all data were kept private and anonymous by assigning each participant a unique identification code. Direct feedback was given to physicians in-charge of patients who were found with VDD, for immediate management.

Study design, site and population

This study used a cross-sectional observational study design. This study was conducted at Mbarara City Health Centre IV, a government health facility which is located in Kamukuzi Division, Mbarara City. It has a functional ART clinic, with approximately 5000 active ART patients. The study population was HIV patients who are currently receiving ART at Mbarara City Health Centre IV. We used simple random sampling to recruit participants from the ART clinic. A thorough explanation was given, and those patients who volunteered to take part and gave consent were recruited into the study.

Eligibility criteria

HIV-positive patients who were 18 years old and above, had been on ART for a minimum of 6 months, who gave both verbal and written consent, and who were willing to provide a blood sample for biochemical analysis, were included. Participants who were critically ill and those who were already on vitamin D supplementation were excluded.

Sample size calculation

The Kish and Leslie sample size formula of 1965 was used, using 17%, a prevalence that was obtained by a study that was carried out among HIV patients at the Infectious Disease Institute in Kampala.[15] Therefore, this study included a minimum of 217 participants.

Study procedure

Participants were randomly selected, and those that fulfilled these research inclusion criteria were enrolled on each of the ART clinic days of the week. The data were collected from 13 August 2024 to 23 August 2024. The principal researcher and the research assistants approached patients at the ART clinic

each day of data collection to explain the goal of the study. Prior to being interviewed by the research assistants using a structured questionnaire that recorded social demographic, behavioural, clinical, and HIV/ART-related factors, patients who consented to participate in the study were asked to sign an informed consent form. The participant was then requested to provide a blood sample to be used for laboratory vitamin D, C-Reactive Protein (CRP), and lipid profile measurement. The samples collected from the facility main laboratory were centrifuged to separate cells and serum, which was stored in the laboratory fridge at 2 °C – 8 °C before analysis, either in the evening of each day of blood sample collection or the following day. The sample was then stored long term in the freezer at -20 °C. This procedure was repeated until the required sample size was achieved.

Data management

Data collection

Data were obtained using a researcher-administered structured questionnaire to obtain information on sociodemographics, lifestyle factors, and participants' knowledge regarding VDD. The clinic records of the eligible individuals were consulted for information regarding HIV disease-related factors. The time of ART initiation, the recent viral load, the current ART regimen, and the length of time on that ART are among the data that were gathered.

A 5 mL venous blood sample was obtained from every study participant in a red-top vacutainer bottle, and it was used to analyse the serum vitamin D levels, CRP levels, triglycerides, high density lipoprotein (HDL), low density lipoprotein (LDL), and total cholesterol concentrations.

Blood specimen collection and analysis

Venous blood (5 mL) was extracted into a red top blood collection vacutainer from each participant according to World Health Organization standard operating procedures. Blood was centrifuged within an hour of collection at 3000 rpm for 10 min, and serum was collected into cryovials and stored at 2 °C – 8 °C before the biochemical analysis and long-term storage at –20 °C.

Laboratory assessment of the biochemical tests

The serum vitamin D (25-hydroxyvitamin D) was measured using the cobas e 411 analyser (Roche Diagnostics GmbH, Mannheim, Germany). Serum samples were transferred into tubes, placed in sample racks, and analysed using the cobas e 411 fully automated immunoassay analyser, with all procedures carried out in line with its instructions for use. The reagent used was Elecsys Vitamin D total III, and calibration was done using the calibrator, CalSet Vitamin D total III.

The serum CRP, triglycerides, HDL cholesterol levels, LDL cholesterol levels, and total cholesterol levels were measured using the cobas c 111 chemistry analyser (Roche Diagnostics GmbH, Mannheim, Germany). The serum samples were carefully transferred into sample tubes. The sample tubes with serum were loaded into sample racks; sample information was entered, and the fully automated testing was started. Biochemical analysis was done using the respective reagents, namely: CRP4, Tina-quant CRP IV for CRP, TRIGL, Triglycerides for triglycerides, CHOL2, Cholesterol Gen.2 for total cholesterol, HDLC4, HDL Cholesterol Gen.4 for HDL cholesterol, and LDLC3, Cholesterol Gen.3 for LDL cholesterol. Dyslipidaemia was defined based on standard cutoffs: total cholesterol $\geq$ 5.2 mmol/L, HDL cholesterol < 1 mmol/L for men or < 1.3 mmol/L for women, triglycerides $\geq$ 1.7 mmol/L, and LDL cholesterol $\geq$ 3.4 mmol/L.

The calibration and quality control of this chemistry analyser was performed using the respective calibrators (C.f.a.s Proteins for CRP, and C.f.a.s Lipids for the lipid parameters) before the biochemical analysis was done.

The manufacturer's instructions for the machines and the reagents were strictly followed. The analysis for 25-hydroxyvitamin D was performed since it is the most abundant form in blood and has a longer half-life, making it a more reliable indicator.[18] The analysers automatically handle all reagent and sample pipetting, incubation, photometric measurements, and computations. They can run any combination of tests on up to 80 samples per work plan.

Anthropometric measurements

All participants underwent anthropometric measurements following World Health Organization guidelines. Weight was measured without shoes using a calibrated Seca Scale (Seca GmbH & Co. KG, Hamburg, Germany), accurate to 0.5 kg. Height was recorded with a stadiometer (Seca GmbH & Co. KG, Hamburg, Germany) to the nearest 0.5 cm while participants stood upright. Body mass index (BMI) was then derived by diving weight in kilograms by height in square metres.

Data storage

Completed consent forms and questionnaires were kept under lock and key, in order to maintain confidentiality of the participants' information. Data were coded, entered into Microsoft Excel 2019 (Microsoft Corporation, Redmond, California, United States), and stored on flash disks and an external drive. These were also kept under lock and key.

Data analysis

Data were entered into Microsoft Excel 2019 and exported to STATA 17.0 (StataCorp LLC, College Station, Texas, United States) for cleaning and analysis. All the studied variables were compared by VDD of the participants at a univariate level to test for statistical difference between two groups, that is, HIV-infected persons with VDD, and those without VDD.

Continuous variables were tested for normality using the Shapiro-Wilk test. We used mean and standard deviation to

summarise the continuous variables which are normally distributed, while those that are not normally distributed were summarised using median and interquartile range. Continuous variable distribution was then compared using Student's *t*-test for means and Wilcoxon rank sum test for medians. Frequencies and proportions were used to describe categorical variables. The significance of categorical variables' association with VDD was tested using the chi-square test and Fisher's exact test for those which had a frequency below 5.

The proportion of patients with VDD and its 95% confidence interval (95%CI) was determined by dividing the total number of participants with VDD by the total number of study participants; this was expressed as a percentage.

Logistic regression analysis was used to assess the factors associated with VDD, which was the dependent binary variable. All independent variables were compared with VDD at a bivariate level. The associations were measured using odds ratio and their 95% CI, and a *p*-value. The variables that were clinically or statistically significant with a *p*-value ≤ 0.2 at this level were assessed in the multivariate model to adjust for confounding. In the final multivariate model, a *p*-value ≤ 0.05 were considered significant.

Results

Characteristics of study participants

The study comprised 218 participants, with a median age of 38 years (interquartile range 30–45). The distribution across age groups was nearly uniform, with 80 (36.7%) participants in each of the 31–40 years and over 40 years age groups. The majority of participants were women (163, 74.8%), and educational attainment was predominantly at the primary level (107, 49.1%), with only 13 (6.0%) having completed tertiary education. Most participants were married or cohabiting (141, 64.7%) and employed (157, 72.0%), with a significant proportion earning less than UGX100000 (115, 52.8%).

Participants' characteristics were grouped by the presence of VDD. A significant difference was observed with BMI, where a higher proportion of individuals with VDD had a BMI of 25 kg/m² or more, as well as CRP levels, with a significant trend towards higher CRP levels in participants with VDD ($p < 0.05$). No significant differences were found in median age, sex, marital status, or employment status between those with and without VDD. Other factors, such as smoking, alcohol consumption, physical activity, and biochemical variables, such as total cholesterol, HDL cholesterol, and LDL cholesterol levels, also did not show significant differences between the two groups ($p > 0.05$) (Table 1, Table 2 and Table 3).

Prevalence of VDD among HIV patients at Mbarara City Health Centre IV

Out of the 218 study participants, 66 had Vitamin D levels < 25 ng/mL, giving an overall prevalence of VDD of 30.3%, with a 95%CI of 24.51% – 36.73%, as indicated in Figure 1.

TABLE 1: Sociodemographic characteristics of study participants stratified by vitamin D deficiency ($N = 218$), at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024.

Variable	Total		Vitamin D deficiency				*p*-value
			Absent ($n = 152$)		Present ($n = 66$)		
	n	%	*n*	%	*n*	%	
Age category (years)	-	-	-	-	-	-	0.88
18–30	58	26.6	39	25.7	19	28.8	-
31–40	80	36.7	57	37.5	23	34.8	-
> 40	80	36.7	56	36.8	24	36.4	-
Sex	-	-	-	-	-	-	0.37
Male	55	25.2	41	27.0	14	21.2	-
Female	163	74.8	111	73.0	52	78.8	-
Education level	-	-	-	-	-	-	0.65
None	33	15.1	23	15.1	10	15.2	-
Primary	107	49.1	76	50.0	31	47.0	-
Secondary	65	29.8	46	30.3	19	28.8	-
Tertiary	13	6.0	7	4.6	6	9.1	-
Marital status	-	-	-	-	-	-	0.19
Single	50	22.9	32	21.1	18	27.3	-
Married/cohabiting	141	64.7	104	68.4	37	56.1	-
Separated/divorced	27	12.4	16	10.5	11	16.7	-
Employment status	-	-	-	-	-	-	0.25
Unemployed	61	28.0	46	30.3	15	22.7	-
Employed	157	72.0	106	69.7	51	77.3	-
Monthly income (UGX, Ugandan Shilling)	-	-	-	-	-	-	1.00
< 100 000	115	52.8	80	52.6	35	53.0	-
100 000–500 000	93	42.7	65	42.8	28	42.4	-
500 000	10	4.6	7	4.6	3	4.5	-

Note: Age (years) median, interquartile range: Total 38, 30–45; Vitamin D deficiency absent 38, 30–45; Vitamin D deficiency present 37.5, 30–45; $p = 0.90$.

TABLE 2: Lifestyle and illness-related characteristics of study participants stratified by vitamin D deficiency (N = 218), at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024.

Variable	Total		Vitamin D deficiency				*p*-value
			Absent (*n* = 152)		Present (*n* = 66)		
	n	%	*n*	%	*n*	%	
Smoking status	-	-	-	-	-	-	0.13
Non-smoker	209	95.9	148	97.4	61	92.4	-
Ever smoked	9	4.1	4	2.6	5	7.6	-
Alcohol consumption	-	-	-	-	-	-	0.16
Never consumed	165	75.7	111	73.0	54	81.8	-
Ever consumed	53	24.3	41	27.0	12	18.2	-
BMI category (kg/m²)	-	-	-	-	-	-	0.039*
< 25	111	50.9	86	56.6	25	37.9	-
25.0–29.9	64	29.4	40	26.3	24	36.4	-
≥ 30	43	19.7	26	17.1	17	25.8	-
Physical activity	-	-	-	-	-	-	0.26
Yes	202	92.7	143	94.1	59	89.4	-
No	16	7.3	9	5.9	7	10.6	-
Sunshine exposure (min)	-	-	-	-	-	-	0.90
< 30	68	31.2	47	30.9	21	31.8	-
≥ 30	150	68.8	105	69.1	45	68.2	-
Duration with HIV (years)	-	-	-	-	-	-	0.63
< 5	58	26.6	39	25.7	19	28.8	-
≥ 5	160	73.4	113	74.3	47	71.2	-
Duration on ART	-	-	-	-	-	-	0.78
≤ 5	73	33.5	50	32.9	23	34.8	-
> 5	145	66.5	102	67.1	43	65.2	-
Viral load	-	-	-	-	-	-	0.069
Detected	14	6.4	13	8.6	1	1.5	-
Non-detected	204	93.6	139	91.4	65	98.5	-
Know what vitamin D is	-	-	-	-	-	-	0.42
Yes	160	73.4	114	75.0	46	69.7	-
No	58	26.6	38	25.0	20	30.3	-
Know what VDD prevention is	-	-	-	-	-	-	0.22
Yes	129	59.2	94	61.8	35	53.0	-
No	89	40.8	58	38.2	31	47.0	-

Note: BMI (kg/m²) median, interquartile range: Total 24.82, 21.95–29.17; Vitamin D deficiency absent: 24.34, 21.93–28.63; Vitamin D deficiency present 26.38, 21.95–30.02; $p = 0.11$.
VDD, vitamin D deficiency; ART, antiretroviral therapy; BMI, body mass index.
*, statistical significance at $p < 0.05$.

Factors associated with VDD among HIV patients at Mbarara City Health Centre IV

After adjustment for confounding effects at multivariate logistic regression analysis, having a BMI of 25–29.9 kg/m² (adjusted odds ratio [aOR]: 2.43; 95%CI:1.18–5.04; *p*-value: 0.016), having a BMI of > 30 kg/m² (aOR: 2.96; 95%CI: 1.18–7.38; *p*-value: 0.020), and having a CRP level of > 5 mg/L (aOR: 2.29 (95%CI: 1.04–5.03; *p*-value: 0.039), were significantly associated with VDD (Table 4).

Discussion

Prevalence of VDD among HIV patients at Mbarara City Health Centre IV

The prevalence of VDD in this study was found to be 30.3% among HIV-positive persons. This prevalence is relatively lower than what has been reported in various studies globally, but still highlights a significant public health concern, as VDD is recognised as a global health issue, with widespread prevalence both in developed and developing countries.[7] The relatively lower prevalence of VDD in our study could possibly be supported by the fact that this was a relatively young population (median age of 38 years), and young people are known to synthesise and produce more vitamin D than older ones, as they have more levels of 7-dehydrocholestrol.[19]

In comparison to global data, our study's prevalence of 30.3% is markedly lower than that from a review study that was found to range from 70.3% to 83.7% after grading it by country.[7] However, the same study found the Ugandan prevalence among HIV patients to be at 35% – 45%, which is relatively similar to our findings. The difference in these prevalences is attributed to the differences in race, ethnicity and lifestyle factors, such as diet, between our population and other countries' data that were analysed in this study.

Our prevalence is also lower than the 60% – 77% VDD prevalence reported in HIV-positive patients in the United States whose study population was only HIV-positive men,[20] as well as the 55.6% prevalence found among HIV-positive individuals in France.[13] This difference can be attributed to the variations in the study population, considering that race is a key player in vitamin D status.[21] Our findings also contrast with those from studies conducted in regions such

TABLE 3: Biochemical tests results characteristics of study participants stratified by vitamin D deficiency (N = 218), at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024.

Variable	Total				Vitamin D deficiency								*p*-value
					Absent (n = 152)				Present (n = 66)				
	Median	IQR	*n*	%	Median	IQR	*n*	%	Median	IQR	*n*	%	
CRP levels (mg/L)†	1.37	0.65–3.67	-	-	1.26	0.64–3.26	-	-	2.005	0.73–4.78	-	-	0.11
CRP levels (mg/L)‡	-	-	-	-	-	-	-	-	-	-	-	-	0.043*
Normal (≤ 5)	-	-	182	83.5	-	-	132	86.8	-	-	50	75.8	-
Elevated (> 5)	-	-	36	16.5	-	-	20	13.2	-	-	16	24.2	-
Total cholesterol (mmol/L)†	3.84	3.36–4.369	-	-	3.81	3.28–4.35	-	-	3.96	3.60–4.36	-	-	0.10
Total cholesterol (mmol/L)‡	-	-	-	-	-	-	-	-	-	-	-	-	1.00
Normal (< 5.13)	-	-	200	91.7	-	-	139	91.4	-	-	61	92.4	-
Elevated (≥ 5.13)	-	-	18	8.3	-	-	13	8.6	-	-	5	7.6	-
Triglycerides (mmol/L)†	1.24	0.98–1.87	-	-	1.3	0.97–1.865	-	-	1.195	0.98–1.94	-	-	0.80
Triglycerides (mmol/L)‡	-	-	-	-	-	-	-	-	-	-	-	-	1.00
Normal (< 1.685)	-	-	151	69.3	-	-	105	69.1	-	-	46	69.7	-
Elevated (≥ 1.685)	-	-	67	30.7	-	-	47	30.9	-	-	20	30.3	-
HDL cholesterol (mmol/L)†	1.13	0.94–1.37	-	-	1.1	0.905–1.37	-	-	1.135	0.97–1.39	-	-	0.77
HDL cholesterol (mmol/L)‡	-	-	-	-	-	-	-	-	-	-	-	-	0.97
Normal (≥ 1.3)	-	-	69	31.7	-	-	48	31.6	-	-	21	31.8	-
Low (< 1.3)	-	-	149	68.3	-	-	104	68.4	-	-	45	68.2	-
LDL cholesterol (mmol/L)†	2.035	1.58–2.42	-	-	1.97	1.545–2.38	-	-	2.115	1.8–2.45	-	-	0.21
LDL cholesterol (mmol/L)‡	-	-	-	-	-	-	-	-	-	-	-	-	0.94
Normal (< 2.56)	-	-	179	82.1	-	-	125	82.2	-	-	54	81.8	-
Elevated (≥ 2.25)	-	-	39	17.9	-	-	27	17.8	-	-	12	18.2	-

CRP, C-reactive protein; HDL, high density lipoprotein; IQR, interquartile range; LDL, low density lipoprotein.

*, statistical significance at $p < 0.05$.

†, continuous variable forms: the medians of each parameter in participants with and without VDD were compared using the Wilcoxon rank sum test; ‡, categorical variable forms: distribution between participants with and without VDD were compared using the Chi-square test.

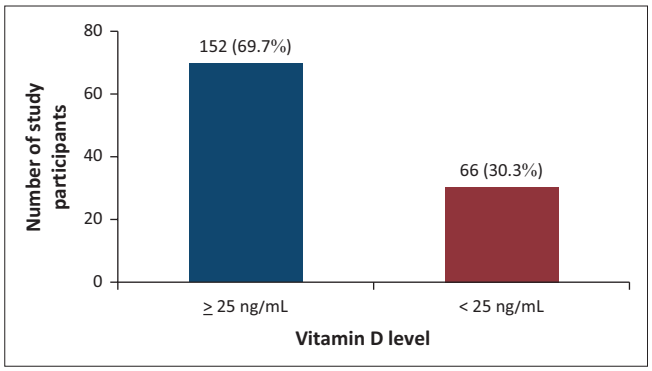

FIGURE 1: Prevalence of vitamin D deficiency among the study participants, at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024 (N = 218).

as Lahore, Pakistan, where a staggering 76% of patients were found to be vitamin D deficient, and 9.4% had severe deficiency.[22] Similarly, a study conducted on a cohort of 2044 HIV patients in Brussels, Belgium, reported an exceptionally high prevalence of 89.2% for VDD.[23] The lower prevalence observed could potentially be linked to differences in the extent of urbanisation, dietary patterns, and levels of outdoor physical activity in south-western Uganda compared to more industrialised settings. Their findings are also in line with the EuroSIDA study that documented an 83% prevalence of VDD.[24] This study randomly selected 2000 participants from within the EuroSIDA study, and their samples were analysed for vitamin D. This very high prevalence of VDD could be because the majority of the participants were sampled during winter, where the sunshine exposure was minimal.

The prevalence we observed aligns more closely with the data from East Africa, where a Kenyan study reported 6.3% of patients as vitamin D deficient, with 29.7% experiencing insufficiency.[25] This similarity in prevalence could be because the Kenyan population is closer to our study population in various aspects, including skin complexion, sun exposure, and diet, which are the major sources of vitamin D.[26] Our study's findings are also relatively higher than another Ugandan study conducted among HIV-positive children, which reported a relatively low prevalence of VDD, at 3%, and insufficiency, at 13%.[27] This difference could be because during infancy and preschool years, children tend to spend more time taking part in outdoor activities, hence get more sunshine exposure compared to the adult population.[28]

A study that was conducted by the Infectious Disease Institute in Uganda found a baseline prevalence of 17% among HIV-infected adults, which was significantly lower than our findings.[15] These lower prevalence rates in Uganda might reflect regional differences in sun exposure (Uganda being a sun-rich country that is crossed by the equator), dietary habits, or other environmental and genetic factors influencing vitamin D metabolism. While the prevalence of VDD in our study is lower compared to other regions, it remains a significant concern given the role of vitamin D in immune function and bone health, especially in HIV-positive individuals who may already be at a higher risk for comorbidities.[4,5,6]

Factors associated with VDD among HIV patients at Mbarara City Health Centre IV

Our study found that higher BMI categories were significantly associated with VDD among HIV-positive individuals. Specifically, individuals with a BMI of 25–29.9 kg/m² had an

TABLE 4: Factors associated with vitamin D deficiency among the study participants at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024.

Variables	Bivariate analysis (cOR)			Multivariate analysis (aOR)		
	Odds ratio	95% CI	*p*-value	Odds ratio	95% CI	*p*-value
Age categories (years)						
18–30	1.00	-	-	1.00	-	-
31–40	0.83	0.40–1.72	0.614	0.89	0.37–2.18	0.805
> 40	0.88	0.42–1.82	0.730	0.48	0.31–2.29	0.738
Sex						
Male	1.00	-	-	1.00	-	-
Female	1.37	0.69–2.74	0.370	1.07	0.47–2.47	0.855
Education level				-		
None	1.00	-	-	-	-	-
Primary	0.94	0.40–2.20	0.883	-	-	-
Secondary	0.95	0.38–2.37	0.912	-	-	-
Tertiary	1.97	0.53–7.37	0.313	-	-	-
Marital status						
Single	1.00	-	-	-	-	-
Married/cohabiting	0.63	0.32–1.26	0.192	-	-	-
Separated/divorced	1.22	0.47–3.19	0.682	-	-	-
Employment status						
Unemployed	1.00	-	-	-	-	-
Employed	1.46	0.75–2.89	0.256	-	-	-
Monthly income (UGX, Ugandan Shilling)						
< 100 000	1.00	-	-	-	-	-
100 000–500 000	0.98	0.54–1.79	0.959	-	-	-
> 500 000	0.98	0.24–4.10	0.977	-	-	-
Smoking status						
Non-smoker	1.00	-	-	-	-	-
Ever smoked	3.02	0.79–11.68	0.107	-	-	-
Alcohol consumption						
Never consumed	1.00	-	-	-	-	-
Ever consumed	0.60	0.29–1.24	0.167	-	-	-
BMI category (kg/m^2)						
< 25	1.00	-	-	1.00	-	-
25.0–29.9	2.07	1.05–4.05	0.035*	2.43	1.18–5.04	0.016*
≥ 30	2.25	1.06–4.79	0.036*	2.96	1.18–7.38	0.020*
Physical activity						
Yes	1.00	-	-	-	-	-
No	1.89	0.67–5.30	0.229	-	-	-
Sunshine exposure (min)						
< 30	1.00	-	-	1.00	-	-
≥ 30	1.04	0.56–1.94	0.895	1.12	0.56–2.21	0.751
Duration with HIV (years)						
< 5	1.00	-	-	1.00	-	-
≥ 5	0.85	0.45–1.63	0.631	0.95	0.27–3.31	0.934
Duration on ART (years)						
≤ 5	1.00	-	-	1.00	-	-
> 5	0.92	0.50–1.69	0.779	0.69	0.20–2.35	0.555
Know vitamin D						
Yes	1.00	-	-	1.00	-	-
No	1.30	0.69–2.48	0.416	0.94	0.35–2.57	0.911
Know VDD prevention						
Yes	1.00	-	-	1.00	-	-
No	1.44	0.80–2.57	0.225	1.74	0.67–0.53	0.255
Meat (days)						
< 4	1.00	-	-	-	-	-
≥ 4	0.93	0.40–2.15	0.871	-	-	-
Milk (days)						
< 4	1.00	-	-	-	-	-
≥ 4	0.82	0.46–1.46	0.490	-	-	-
Fish (days)						
< 4	1.00	-	-	-	-	-
≥ 4	0.56	0.06–5.19	0.617	-	-	-

Table 4 continues on the next page →

TABLE 4 (Continues...): Factors associated with vitamin D deficiency among the study participants at Mbarara City Health Centre IV, from 13 August 2024 to 23 August 2024.

Variables	Bivariate analysis (cOR)			Multivariate analysis (aOR)		
	Odds ratio	95% CI	*p*-value	Odds ratio	95% CI	*p*-value
CRP (mg/L)						
Normal (≤ 5)	1.00	-	-	1.00	-	-
Elevated (> 5)	2.11	1.01–4.40	0.046*	2.29	1.04–5.03	0.039*
Total cholesterol (mmol/L)						
Normal (< 5.13)	1.00	-	-	1.00	-	-
Elevated (≥ 5.13)	0.88	0.30–2.57	0.810	0.96	0.24–3.85	0.955
Triglycerides (mmol/L)						
Normal (< 1.685)	1.00	-	-	1.00	-	-
Elevated (≥ 1.685)	0.97	0.52–1.82	0.928	0.93	0.45–1.91	0.842
HDL cholesterol (mmol/L)						
Normal (≥ 1.3)	1.00	-	-	1.00	-	-
Low (< 1.3)	0.99	0.53–1.84	0.972	1.03	0.52–2.07	0.926
LDL cholesterol (mmol/L)						
Normal (< 2.56)	1.00	-	-	1.00	-	-
Elevated (≥ 2.25)	1.03	0.49–2.18	0.941	0.81	0.30–2.13	0.663

ART, antiretroviral therapy; CRP, C-reactive protein; aOR, adjusted odds ratio; cOR, crude odds ratio; 95% CI, 95% confidence interval; VDD, vitamin D deficiency, HDL, high density lipoprotein; LDL, low density lipoprotein.

*, indicates statistical significance at $p < 0.05$.

aOR of 2.43, indicating more than double the likelihood of VDD compared to those with a normal BMI. Additionally, individuals with a BMI greater than 30 kg/m² had an even higher aOR of 2.96, suggesting nearly a threefold increased risk of VDD.

These findings align with previous research, indicating that both being overweight and obesity are linked to an increased risk of VDD in the context of HIV infection.[29,30,31] These studies focused on the factors associated with VDD in a population that is similar to the current study, that is HIV patients. This relationship may be explained by the fact that vitamin D, being fat-soluble, is sequestered in adipose tissue, leading to lower circulating levels of the vitamin in individuals with higher body fat percentages.[32] Contrary to our study, a study carried out among HIV-infected and HIV-uninfected individuals found that lower BMI was associated with VDD.[33] This contradiction can be attributed to the difference in the geographical location of the participants since it only included those from Europe, the middle and east of Asia, America, and Australia.

Our study also identified a significant association between VDD and elevated CRP levels (> 5 mg/L aOR: 2.29) in HIV-positive individuals, indicating that VDD is linked to increased inflammation. This finding is consistent with existing research, which has shown that VDD in HIV patients is associated with greater inflammation and immune dysfunction.[7,33] The study by Mansueto et al.[7] is a review article, and it focused on various markers of inflammation, including CRP. It also suggested that there seems to be a considerable overlap in the outcomes associated with VDD and chronic inflammation, in both HIV-infected and -uninfected individuals.

Our results align closely with those of Manion et al.,[9] who found that HIV-infected individuals with VDD had higher levels of inflammatory markers such as IL-6, TNF-α, hsCRP, and D-dimer. Ansemant et al.[34] also reported a similar link between VDD and increased immune activation in HIV patients. These consistent findings across different studies suggest that the relationship between VDD and heightened inflammation is a common occurrence in HIV-positive populations. This relationship was also suggested by a study by Shepherd et al.,[35] who found a significant association with VDD and IL-6, although there was no association with CRP (contrary to our study). This contradiction can be attributed to a difference in the ethnicity and geographical location, since the study involved participants from various countries, all of which were European countries. However, a study by Hoffman et al.[36] did not find an association between VDD and markers of inflammation. This difference could be attributed to the fact that their study only enrolled participants on ART with documented HIV-1 RNA < 200 copies/mL, and also analysed samples that had been stored at participant's baseline visit.

Study limitations

This was a cross-sectional study, therefore the cause-effect relationship between the exposure variables; overweight, obesity, and elevated CRP with the outcome variable VDD remain unclear.

Recommendations

We recommend routine screening for VDD among HIV-infected persons with elevated CRP and BMI. Nutritional support, including vitamin D supplementation and dietary counselling, could be integrated into HIV care programmes to address VDD. A prospective study should be conducted to further investigate the risk of developing VDD among HIV patients that are overweight, obese, and those with elevated CRP levels.

Conclusion

The study found a 30.3% prevalence of VDD among HIV-positive individuals at Mbarara City Health Centre IV. Key

associated factors included higher BMI and elevated inflammation (CRP levels). Our study underscores the importance of addressing both obesity and inflammation in the management of HIV-infected persons.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

J.T., C.N.B., D.N., E.S., B.R., F.S., W.R.M., R.K., and S.P.R. contributed equally to the conceptualisation, writing, and editing of the article, and share first authorship. All authors contributed to the article, discussed the results, and approved the final version for submission and publication.

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Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author, J.T., upon reasonable request.

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