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Prevalence of vitamin D deficiency and its association with adverse obstetric outcomes among pregnant women in Uganda: a cross-sectional study

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ABSTRACT

Objective There is a dearth of published data on the vitamin D status of the Ugandan population; the objective of the study was to determine the prevalence of vitamin D deficiency among pregnant women in Uganda and its associations with maternal characteristics and adverse foetal-maternal outcomes.

Study design and setting We conducted a cross-sectional study on pregnant women admitted to a tertiary referral hospital in Kampala, Uganda for delivery during the study period from July to December 2023.

Participants The study was conducted on 351 pregnant women aged ≥18 years who consented to participate in the study, who had a single intrauterine pregnancy and a gestational age greater than 26 weeks, and who delivered at St. Francis Hospital, Nsambya. We excluded pregnant women admitted to the hospital longer than 1 week before delivery; pregnant women with self-reported pre-existing kidney diseases, liver diseases, or gut or malabsorption disorders and pregnant women with severe pregnancy-unrelated comorbidities requiring intensive care unit admission before delivery.

Interventions Maternal venous blood was collected at admission, and serum 25-hydroxy-vitamin D (25(OH)D) was measured by an electrochemiluminescence binding assay.

Primary and secondary outcome measures Maternal sociodemographic characteristics and obstetric-medical factors, and adverse maternal and foetal outcomes were captured by using a data collection form. The data were analysed by logistic regression analysis at the univariate, bivariate and multivariate levels.

Results The prevalence of vitamin D deficiency, defined as a serum 25(OH)D concentration less than 20 ng/mL, was 40.2%. This was seen more among the Muslims (OR 2.4, 95% CI 1.33 to 4.43, p value 0.004), members of the Banyankore tribe (OR 2.1, 95% CI 1.02 to 4.36, p value 0.043) and primigravidae (OR 0.6 for women with parity of 1–4 compared with primigravidity, 95% CI 0.36 to 0.94, p value 0.028). Among adverse maternal outcomes, vitamin D deficiency was associated with hypertensive disorders in pregnancy (OR 2.4, 95% CI 1.16 to 4.10, p value <0.001), in particular gestational hypertension (OR 2.2, 95% CI 1.21 to 4.94, p value 0.014), and pre-eclampsia/eclampsia/haemolysis, elevated liver enzymes and low platelets syndrome (OR 2.9, 95% CI 1.45 to 6.08, p value 0.003), with increased preterm birth (OR of 4.0, 95% CI 1.78 to 10.84, p value<0.001) and with delivery of babies with low birth weight (OR 4.2, 95% CI 2.63 to 13.62, p value 0.001).

Conclusions The study found a high prevalence (40.2%) of vitamin D deficiency among pregnant women delivering at St. Francis Hospital, Nsambya. Additionally, vitamin D deficiency was linked with adverse maternal and foetal outcomes such as hypertensive disorders in pregnancy, preterm birth and low birth weight.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ To the best of our knowledge, this is the first study to examine the prevalence of vitamin D deficiency among pregnant women at delivery in Uganda and to analyse the association between vitamin D deficiency and adverse foetal-maternal outcomes.
⇒ The study used a validated assay for the quantitative determination of serum 25-hydroxy-vitamin D, carried out at an internationally accredited laboratory.
⇒ The cross-sectional nature of the study may only establish the presence of associations of vitamin D deficiency with maternal characteristics and obstetric outcomes, but is not suitable for confirming causation.
⇒ Potential sources of bias were not available for analysis in the present study, such as information about participants' diet, sunlight exposure and physical activity.
⇒ Participants were not selected based on ethnicity or skin type/pigmentation, although women were largely black.

BACKGROUND

The prevalence of vitamin D deficiency differs in various parts of the world based on ethnicity, latitude, environmental factors and sociocultural practices; vitamin D deficiency is more common in urban areas than in rural areas, in women than in men and in pregnant women than in nonpregnant women.[1] In the African populations, the prevalence of vitamin D deficiency, defined as a serum 25-hydroxy-vitamin D (25(OH)D)

concentration less than 50 nmol/L (20 ng/mL), is 34%.[2] Skin hyperpigmentation is considered one of the major risk factors for vitamin D deficiency[3]; in fact, the most important source of vitamin D for humans is its production in the skin through exposure to UV-B radiation, which may be reduced by the melanin contained in the skin. In Uganda, there is a paucity of data in the literature on vitamin D deficiency in the general population.

Many studies have indicated the importance of vitamin D in fertilisation, placental development, the course of pregnancy and offspring health. Vitamin D shows anti-inflammatory and immunosuppressive properties, with a relevant influence on placental implantation, the immune system and angiogenic factors.[4] The levels of vitamin D physiologically increase during pregnancy, almost doubling by the end of the third trimester and returning to normal after delivery; in fact, maternal 25(OH)D crosses the placenta and is the main form of vitamin D for the foetus. In addition to increasing calcium absorption to meet the demands of adequate foetal bone mineralisation, vitamin D also plays a major role in placental physiology.[5] Recent observational studies have demonstrated that a low vitamin D status in pregnancy is associated with multiple potential adverse maternal, foetal and infant outcomes.[6 7] It is presumed that several pregnancy complications (eg, pre-eclampsia, preterm birth and gestational diabetes mellitus (GDM)) and complications manifesting in offspring later in life (eg, asthma, psychomotor development and cognitive disorders) could be the effects of vitamin D deficiency.[4–6] Moreover, vitamin D supplementation during pregnancy may reduce the risk of pre-eclampsia, GDM, low birth weight and severe postpartum haemorrhage (PPH).[7] Nevertheless, these associations have been studied predominantly in white populations, and there is little evidence of associations between vitamin status and foetal and maternal outcomes in African countries; for instance, the cited review of Palacios *et al*[7] did not consider any study conducted in African countries or on black populations.

Regarding hypertensive disorders in pregnancy, there is conflicting evidence on whether hypovitaminosis D is associated with hypertension and pre-eclampsia; while various studies have shown that deficient maternal 25(OH)D levels are associated with up to a fivefold increased risk of severe pre-eclampsia, other studies have failed to demonstrate this relationship.[1 8] This is particularly relevant in black women, who have a greater prevalence of pre-eclampsia than white women and who have more severe forms of the disease.[9]

Moreover, data on vitamin D status in pregnant women in Uganda are missing. Two studies have been reported in the literature: the first study conducted in rural Uganda examined the status of micronutrients, including vitamin D, in HIV-infected women initiating antiretroviral therapy,[10] while the second study addressed the impact of vitamin D on *Escherichia coli* infection during pregnancy.[11] We aimed to determine the burden of vitamin D deficiency, its association with maternal characteristics and its association with adverse obstetric outcomes among pregnant women in Uganda.

METHODS

Study design and setting

We conducted a cross-sectional study of 351 women who met the eligibility criteria and who were admitted to St. Francis Hospital, Nsambya, for delivery during the study period from July to December 2023.

Study site

This research was carried out in the Department of Obstetrics and Gynaecology of St. Francis Hospital, Nsambya, a private not-for-profit hospital accredited by the Uganda Catholic Medical Bureau and operated by the Little Sisters of St. Frances. The hospital lies approximately 5 km southeast of the central business district of Kampala; it has a catchment area with a 21 km radius and a catchment population of nearly 1.7 million. The hospital offers inpatient and outpatient services. The Department of Obstetrics and Gynaecology offers delivery services, with approximately 250 deliveries per month.

Study population

The study population included all women who met the eligibility criteria and who delivered at St. Francis Hospital, Nsambya, both vaginally and by caesarean section (C/S) during the study period.

Eligibility criteria

The study enrolled pregnant women aged ≥18 years who consented to participate in the study, who had a single intrauterine pregnancy and a gestational age greater than 26 weeks, and who delivered at St. Francis Hospital, Nsambya.

We excluded pregnant women admitted to the hospital longer than 1 week before delivery; pregnant women with self-reported pre-existing kidney diseases, liver diseases, or gut or malabsorption disorders and pregnant women with severe pregnancy-unrelated comorbidities requiring intensive care unit (ICU admission before delivery.

Sample size and sampling method

The sample size was estimated by using the formula suggested by Kish Leslie, with a 95% CI and a precision of 5%, using a prevalence of 25(OH)D deficiency of 34.18%, based on a meta-analysis of 130 studies conducted in 23 African countries.[2] The obtained sample size was 346 women; participants were selected by systematic random sampling.

Patient recruitment

Patients who were admitted for delivery to the Department of Obstetrics and Gynaecology were screened for eligibility for participation in this study. Patients who met the inclusion criteria were informed about the study, and patients who agreed to participate in the study were enrolled after providing written informed consent.

Blood sample retrieval and analytical methods

Maternal serum 25(OH)D levels were analysed at hospital admission for delivery. Venous blood samples were retrieved by using red-top Vacutainer blood collection tubes under sterile conditions. Blood samples were promptly delivered to the Laboratory Department of St. Francis Hospital, Nsambya, a laboratory accredited by the South African National Accreditation System (Standard ISO 15189:2012 of 2018), where the analyses were conducted. Details of the analytical method used for the quantitative determination of serum 25(OH)D are reported in online supplemental file 1.

Data collection and data sources

The sociodemographic characteristics (age, tribe, educational level, religion, marital status and occupation) and obstetric-medical data of the patients (gravidity, parity, gestational age at delivery, booking body mass index and vitamin supplement intake at admission) were obtained directly from the patients at admission and from their charts, and recorded on a pretested data collection form. More specifically, the tribe of the participants was requested in an open question and self-defined by the participants. Participants were followed up at delivery, and foetal and maternal outcome details were collected in the corresponding data collection forms, that is, delivery mode, admission to high-dependency unit (HDU) or ICU, gestational hypertension, pre-eclampsia, eclampsia, haemolysis, elevated liver enzymes and low platelets (HELLP) syndrome, GDM, PPH, prelabour rupture of membranes (PROM), antepartum haemorrhage (APH), term delivery, birth weight, APGAR scores at 1 and 5 min, and neonate admission to nursery or neonatal ICU (NICU).

Data management

The data collection forms were regularly examined for accuracy and completeness; double data entry was performed with KoboToolbox 2 and the coded data were then exported to STATA 17 for analysis. The completed data collection forms were kept under lock and key, and the data were entered into a password-protected computer; confidentiality was guaranteed throughout the study period.

Data analysis

The data were analysed at the univariate, bivariate and multivariate levels using the STATA 17 statistical package. In the univariate analysis, descriptive statistics were obtained for the selected variables. Categorical variables are presented as frequencies and percentages, while continuous variables are presented as medians or means. The prevalence of 25(OH)D deficiency was obtained by dividing the number of women diagnosed with 25(OH)D deficiency by the total number of women recruited. The prevalence of the outcomes was determined as the proportion of participants who experienced such outcomes as a percentage of the total sample size, assuming a 95% CI.

Binary logistic regression analysis was conducted to assess maternal characteristics and maternal and foetal outcomes associated with 25(OH)D deficiency. In the crude analysis, the crude ORs together with their 95% CIs and p values are presented. All variables with p values ≤0.2 were selected for adjusted multivariate analysis using the forward selection technique. In the multivariate analysis, adjusted ORs (aORs), together with the 95% CIs and p values, are presented. All variables with p values lower than 0.05 were significant at the 5% level.

Patient and public involvement

Patients and the public were not involved in the design of the study.

RESULTS

Characteristics of the study participants

Most of the participants were Baganda (159, 45.3%) and Christian (289, 82.3%). Most of the participants were overweight or obese (139, 39.8% and 128, 36.7%, respectively), had a parity of 1–4 (233, 66.4%), were HIV-negative (338, 96.6%), were using iron supplements (332, 94.6%) and had normal haemoglobin levels (311, 88.6%). Almost half of the participants declared at admission that they used a supplement containing calcium and vitamin D (174, 49.6%). The baseline characteristics of the participants included in the study are summarised in table 1.

Adverse maternal and foetal outcomes

The majority of the participants delivered by C/S (184, 52.4%) and 315 participants (89.7%) did not require admission to HDU or ICU. The prevalence of hypertensive disorders in pregnancy was 21.1% (74): 36 participants (10.2%) suffered from gestational hypertension, 34 (9.7%) from pre-eclampsia, 2 from eclampsia and 2 from HELLP syndrome. The other maternal conditions analysed, that is, GDM, PPH, PROM and APH showed a single-digit prevalence. The vast majority of the participants delivered term babies (322, 91.7%) with a normal birth weight (310, 88.3% with a birth weight of 2.5–3.9 kg); 98.6% (346) of the deliveries resulted in live births, for the vast majority with good APGAR scores of ≥7 at 1 min (322, 91.8%) and at 5 min (341, 97.2%), although a relevant proportion of neonates (113, 32.2%) required admission to nursery or NICU for monitoring or management. During the study period, there were five stillborn neonates (1.4%), all of which were macerated stillborn; four of these cases were secondary to pre-eclampsia with severe features, while in the last case, the patient was HIV-positive on antiretroviral therapy and presented to the hospital with a foetal demise. Table 2 summarises the adverse maternal and foetal outcomes of the participants who delivered at St. Francis Hospital, Nsambya, during the study period.

Table 1 Maternal characteristics of the study participants (N = 351), St. Francis Hospital, Uganda, 2023

Variable	Absolute frequency (n)	Relative frequency (%)
Maternal sociodemographic characteristics		
Tribe		
Baganda	159	45.3
Banyankore	39	11.1
Basoga	21	6.0
Bakiga	20	5.7
Other	112	31.9
Religion		
Christian	289	82.3
Muslim	55	15.7
Other	7	2.0
Maternal obstetric-medical characteristics		
Parity		
Mean (SD)	1.8 (1.6)	
Parity category		
0	107	30.5
1–4	233	66.4
>4	11	3.1
Booking BMI (kg/m^2)		
Mean (SD)	29.0 (5.5)	
Booking BMI category (kg/m^2)		
Normal (18.5–24.9)	82	23.5
Overweight (25.0–29.9)	139	39.8
Obese (≥30)	128	36.7
HIV status		
Negative	338	96.6
Positive	12	3.4
Haemoglobin (g/L)		
Mean (SD)	124 (13)	
Haemoglobin category (g/L)		
≥110	311	88.6
80–109	40	11.4
Supplements taken at admission		
Iron supplements		
Ferroton	240	68.4
Ferrobin	59	16.8
Pregnacare	21	6.0
Fefol	12	3.4
None	19	5.4
Calcium-vitamin D supplements		
Calcivita (400 IU D3)	139	39.6
Pregnacare (400 IU D3)	21	6.0
Ozical (50 IU D3)	7	2.0
Calcitron (67 IU D3)	7	2.0
None	177	50.4
Supplement combinations		
Ferroton + Calcivita (400 IU D3)	110	31.3
Ferrobin + Calcivita (400 IU D3)	30	8.5

BMI, body mass index.

Prevalence of serum 25(OH)D deficiency

The serum 25(OH)D concentrations of the participants showed a slightly right-skewed distribution, with a median value of 23.79 ng/mL (minimum of 3.67 and maximum values of 56.17 ng/mL, and a kurtosis value of 2.6), a mean of 24.36 ng/mL and a SD of 11.20 ng/mL. The prevalence of vitamin D deficiency, defined as a serum 25(OH)D concentration <20 ng/mL (ie, <50 nmol/L), in pregnant women at delivery at St. Francis Hospital, Nsambya, during the study period, was 40.2% (95% CI of 35.0 to 45.5). Only 28.2% (95% CI of 23.6 to 33.2) of the women had normal values of vitamin D, while vitamin D insufficiency and severe deficiency were measured in 71.8% (95% CI of 66.8 to 76.6) and 13.4% (95% CI of 10.0 to 17.4) of the participants, respectively. The vitamin D status of the participants, categorised according to Holick,[12] is reported in table 3.

Multivariate analysis assessing the association between maternal characteristics and vitamin D deficiency

The data were first analysed at the bivariate level, and to eliminate possible confounders, all variables with p values ≤0.2 in the bivariate analysis were selected for adjusted multivariate analysis using the forward selection technique. The following factors were considered for adjusted analysis: maternal religion, tribe, parity, HIV status, haemoglobin value, supplements taken at admission, maternal outcomes (admission to HDU/ICU, hypertensive disorders in pregnancy and gestational age at delivery) and foetal outcomes (pregnancy outcome, APGAR scores at 1 and 5 min, and birth weight).

After multivariate adjustment, Muslim women were 2.4 times more likely to have vitamin D deficiency than Christian women (aOR of 2.43, 95% CI of 1.33 to 4.43, p value 0.004). Compared with Baganda participants, women in the Banyankore tribe were twice as likely to have vitamin D deficiency (aOR of 2.11, 95% CI of 1.02 to 4.36, p value 0.043). Multivariate analysis confirmed that a parity ranging from 1 to 4 was a protective factor against vitamin D deficiency, compared with primigravidae women (aOR of 0.58 for parity 1–4, 95% CI of 0.36 to 0.94, p value 0.028). The results confirm the protective effect conferred by the use of Calcivita (aOR of 0.58, 95% CI of 0.36 to 0.95, p value 0.031) and the synergistic protective effect of the combination of Ferroton and Calcivita (aOR of 0.48, 95% CI of 0.35 to 0.91, p value 0.041).

The aORs, together with the 95% CIs and p values for maternal characteristics, are reported in table 4.

Table 2 Adverse maternal and foetal outcomes (N = 351), St. Francis Hospital, Uganda, 2023

Adverse maternal and foetal outcomes	Absolute frequency (n)	Relative frequency (%)
Maternal outcomes		
Mode of delivery		
C/S	184	52.4
Vaginal	167	47.6
Admission to HDU/ICU		
No	315	89.7
Yes	36	10.3
Hypertensive disorders in pregnancy	74	21.1
Gestational hypertension	36	10.2
Pre-eclampsia	34	9.7
Eclampsia	2	0.6
HELLP	2	0.6
Pre-eclampsia, eclampsia or HELLP	38	10.8
GDM	13	3.7
PPH	13	3.7
PROM	7	2.0
APH	2	0.6
Gestational age at delivery (weeks)		
≥37	322	91.7
<37	29	8.3
Foetal outcomes		
Outcome		
Live birth	346	98.6
Stillbirth	5	1.4
APGAR at 1 min		
7–10	322	91.8
4–6	18	5.1
<4	11	3.1
APGAR at 5 min		
7–10	341	97.2
4–6	4	1.1
<4	6	1.7
Birth weight (kg)		
2.5–3.9	310	88.3
<2.5	23	6.6
≥4	18	5.1
Admission to nursery/NICU		
Yes	113	32.2
No	238	67.8

APH, antepartum haemorrhage; C/S, caesarean section; GDM, gestational diabetes mellitus; HDU, high-dependency unit; HELLP, haemolysis, elevated liver enzymes and low platelets; ICU, intensive care unit; NICU, neonatal intensive care unit; PPH, postpartum haemorrhage; PROM, prelabour rupture of membranes.

Multivariate analysis assessing the association between vitamin D deficiency and adverse maternal and foetal outcomes

The following factors were considered for adjusted analysis: maternal religion, tribe, parity, HIV status, haemoglobin value, supplements taken at admission, maternal outcomes (admission to HDU/ICU, hypertensive disorders in pregnancy and gestational age at delivery) and foetal outcomes (pregnancy outcome, APGAR scores at 1 and 5 min, and birth weight).

According to multivariate analysis, women with vitamin D deficiency were more likely to be admitted to HDU or ICU (aOR of 1.74) than women without vitamin D deficiency, but the difference was not significant (95% CI of 0.86 to 3.53, p value 0.127). Regarding hypertensive disorders in pregnancy, the results indicated a 2.4-fold greater likelihood of these conditions in women with vitamin D deficiency (aOR 2.44, 95% CI of 1.16 to 4.10, p value < 0.001). For single hypertensive disorders, the aORs were 2.19 for gestational hypertension (95% CI of 1.21 to 4.94, p value 0.014) and 1.81 for pre-eclampsia (not significant, 95% CI of 0.92 to 3.67, p value 0.103). When considering the most severe forms of hypertensive disorders, that is, pre-eclampsia, eclampsia and HELLP syndrome, women with vitamin D deficiency were almost three times more likely to suffer from such conditions (aOR of 2.86, 95% CI of 1.45 to 6.08, p value 0.003). Maternal vitamin D deficiency was associated with an increased likelihood of preterm birth (aOR of 3.99, 95% CI of 1.78 to 10.84, p value<0.001). Finally, concerning foetal outcomes, vitamin D deficiency was associated with APGAR scores <4 at 1 min (aOR of 8.92, 95% CI of 3.38 to 62.9, p value 0.004) but not at 5 min, as well as with lower birth weights (aOR of 4.16 for birth weight<2.5 kg, 95% CI of 2.63 to 13.62, p value 0.001); nevertheless, a maternal-deficient vitamin D status was not significantly associated with more frequent admission of the neonate to nursery or NICU.

The maternal and foetal outcomes independently associated with vitamin D deficiency, as determined by multivariate analysis, are reported in table 5.

DISCUSSION

The present study remedies the lack of information concerning vitamin D deficiency in Uganda and its association with adverse maternal and foetal outcomes. The prevalences of 25(OH)D deficiency and severe deficiency were 40.2% and 13.4%, respectively.

Compared with Christian women, Muslim women were 2.4 times more likely to have vitamin D deficiency, and women in the Banyankore tribe were twice as likely to have vitamin D deficiency than Baganda. Moreover, a parity of 1–4 was a protective factor for vitamin D deficiency versus primigravidity. The obtained data did not show any significant association between maternal obesity and low vitamin D status. The use of specific calcium supplements containing low doses of vitamin D during antenatal care (ANC), both alone and in combination with iron compounds, showed a protective effect against vitamin D deficiency.

The present study revealed a significant association between maternal vitamin D deficiency and hypertensive disorders in pregnancy; when considering pre-eclampsia,

Table 3 Categories of serum 25(OH)D in the study participants (N = 351), St. Francis Hospital, Uganda, 2023

Category	Definition serum 25(OH)D (ng/mL)	Absolute frequency (n)	Relative frequency (%)	95% CI	Cumulative frequency (%)
Severe deficiency	<12.0	47	13.4	10.0 to 17.4	13.4
Deficiency	12 to <20	94	26.8	22.2 to 31.7	40.2
Insufficiency	20 to <30	111	31.6	26.8 to 36.8	71.8
Normal	≥30	99	28.2	23.6–33.2	100.0
Total		351	100.0		

25(OH)D, 25-hydroxy-vitamin D.

eclampsia and HELLP collectively, women with vitamin D deficiency had a 2.86-fold greater likelihood of suffering from one of these conditions. The results also revealed a fourfold increase in preterm birth among pregnant women with vitamin D deficiency. The present study did not show any association between deficient vitamin D status and maternal admission to HDU/ICU, as well as other maternal complications, such as GDM, APH, PPH and PROM. Maternal vitamin D deficiency was associated with lower APGAR scores at 1 min and with lower birth weights. The associations with stillbirths and neonatal admission to nursery/NICU were not statistically significant.

Prevalence of vitamin D deficiency in Ugandan pregnant women

The present study revealed a high burden of vitamin D deficiency in Ugandan pregnant women at delivery; the prevalence of 25(OH)D insufficiency of 71.8% is well above the global level of 54% estimated by Saraf *et al* in pregnant women.[13] Moreover, the prevalence of 25(OH)D deficiency of 40.2% is higher than the 34% reported in the literature for the African general population.[2] These data support the position of Mogire *et al* that Africa could be the continent with the greatest vitamin D deficiency, thus correcting the misconception that low vitamin D is rare in sub-Saharan countries, which are characterised by abundant sunshine.

Association of maternal characteristics with vitamin D deficiency

The study confirmed the association between Muslim religion and vitamin D deficiency; this risk factor, which is well known in the literature, may be attributed to inadequate exposure of the skin to sunlight due to conservative dress styles that cover most of the body when Muslim women are outdoors, thus decreasing the potential for cutaneous vitamin D production.[14] A possible explanation for the increased likelihood of vitamin D deficiency in Banyankore women compared to women of the Buganda tribe is nutritional diversity and different dietary customs. Finally, the protective effect of parity versus primigravidity on vitamin D deficiency may be explained by nutritional deficiencies in young primigravidae individuals. The obtained data were not able to show any significant association between maternal obesity and low vitamin D status, although in the literature, obesity is considered an independent determinant of vitamin D deficiency.[14]

Associations between vitamin D deficiency and adverse obstetric outcomes

This study revealed a significant association between maternal vitamin D deficiency and hypertensive disorders in pregnancy; this result is particularly relevant since these disorders tend to be more prevalent and severe among black women.[9] Worldwide, hypertensive disorders account for approximately 14% of all maternal deaths[15] and 16% of maternal deaths in Uganda.[16] Among the hypertensive disorders that complicate pregnancy, pre-eclampsia, eclampsia and HELLP syndrome stand out as major causes of maternal and perinatal mortality and morbidity; collectively, in the present study, women with vitamin D deficiency had an almost threefold greater likelihood of suffering from one of these conditions. These findings are in line with the results of previous studies.[8] Several hypotheses may explain the influence of hypovitaminosis D on the pathophysiology of pre-eclampsia, such as the role of vitamin D in the modulation of proinflammatory responses and in the decrease in oxidative stress, further promoting angiogenesis through vascular endothelial growth factor.[1] Moreover, vitamin D is considered a significant modulator of both innate and adaptive immunity by regulating cell proliferation, differentiation and apoptosis. Vitamin D also regulates endothelial and vascular smooth muscle cell proliferation and therefore plays a role in regulating blood pressure through the renin–angiotensin–aldosterone system.[5]

This study revealed significant associations between deficient vitamin D status and preterm birth, which is in line with previous publications.[7] Regarding adverse foetal outcomes, maternal deficient vitamin D status was significantly associated with lower APGAR scores at 1 min and with lower birth weights, in line with previous studies reported in the literature.[7 8]

Strengths and limitations

To the best of our knowledge, this is the first study to examine the prevalence of vitamin D deficiency among

Table 4 Association between maternal characteristics and vitamin D deficiency (N = 351), St. Francis Hospital, Uganda, 2023

Variable	n (%) Vitamin D <20 ng/mL	n (%) Vitamin D ≥20 ng/mL	aOR	95% CI	P value
Tribe					
Baganda	58 (41.1)	101 (48.1)	1.0		
Banyankore	**20 (14.2)**	**19 (9.0)**	**2.11**	**1.02 to 4.36**	**0.043**
Basoga	11 (7.8)	10 (4.8)	2.10	0.83 to 5.33	0.116
Bakiga	4 (2.8)	16 (7.6)	0.54	0.17 to 1.71	0.295
Other	48 (34.0)	64 (30.5)	1.35	0.80 to 2.25	0.257
Religion					
Christian	105 (74.5)	184 (87.6)	1.0		
Muslim	**31 (22.0)**	**24 (11.4)**	**2.43**	**1.33 to 4.43**	**0.004**
Other	5 (3.5)	2 (1.0)	3.78	0.70 to 20.31	0.122
Parity					
0	53 (37.6)	54 (25.7)	1.0		
1–4	**84 (59.6)**	**149 (70.9)**	**0.58**	**0.36 to 0.94**	**0.028**
>4	4 (2.8)	7 (3.3)	0.86	0.23 to 3.25	0.825
HIV status					
Positive	2 (1.4)	10 (4.8)	1.0		
Negative	139 (98.6)	199 (95.2)	4.28	0.87 to 20.94	0.073
Haemoglobin (g/L)					
80–109	21 (14.9)	19 (9.0)	1.0		
≥110	120 (85.1)	191 (91.0)	0.52	0.25 to 1.07	0.074
Iron supplements					
None	5 (3.5)	14 (6.7)	1.0		
Ferroton	90 (63.8)	150 (71.4)	1.97	0.65 to 5.88	0.227
Ferrobin	27 (19.1)	32 (15.2)	2.70	0.83 to 8.87	0.099
Pregnacare	14 (9.9)	7 (3.3)	3.56	0.34 to 36.70	0.286
Fefol	5 (3.5)	7 (3.3)	1.74	0.35 to 8.52	0.507
Calcium-vitamin D supplements					
None	76 (53.9)	101 (48.1)	1.0		
Calcivita	**43 (30.5)**	**96 (45.7)**	**0.58**	**0.36 to 0.95**	**0.031**
Pregnacare	14 (9.9)	7 (3.3)	1.45	0.18 to 11.63	0.724
Ozical	4 (2.8)	3 (1.4)	1.89	0.38 to 9.27	0.432
Calcitron	4 (2.8)	3 (1.4)	2.11	0.43 to 10.34	0.358
Supplement combinations					
Ferroton + Calcivita					
No	106 (75.7)	134 (63.8)	1.0		
Yes	**34 (24.3)**	**76 (36.2)**	**0.48**	**0.35 to 0.91**	**0.041**

Variables with p values lower than 0.05, considered to be significant at the 5% level, are highlighted in bold.
aOR, adjusted OR.

pregnant women at delivery in Uganda and to analyse the association between vitamin D deficiency and adverse foetal-maternal outcomes. A further strength of the study was the use of a validated assay for the quantitative determination of serum 25(OH)D, which was carried out at an internationally accredited laboratory.

Despite the above strengths, a few limitations must be acknowledged. The cross-sectional nature of the study,

Table 5 Association between vitamin D deficiency and adverse obstetric outcomes (N = 351), St. Francis Hospital, Uganda, 2023

Variable	n (%) Vitamin D < 20 ng/mL	n (%) Vitamin D ≥ 20 ng/mL	aOR	95% CI	P value
Maternal outcomes					
Admission to HDU/ICU					
No	121 (85.8)	194 (92.4)	1.0		
Yes	20 (14.2)	16 (7.6)	1.74	0.86 to 3.53	0.127
Hypertensive disorders in pregnancy					
No	96 (68.6)	181 (85.8)	1.0		
Yes	**44 (31.4)**	**30 (14.2)**	**2.44**	**1.16 to 4.10**	**<0.001**
Gestational hypertension					
No	119 (85.0)	196 (92.9)	1.0		
Yes	**21 (15.0)**	**15 (7.1)**	**2.19**	**1.21 to 4.94**	**0.014**
Pre-eclampsia					
No	121 (86.4)	196 (92.9)	1.0		
Yes	19 (13.6)	15 (7.1)	1.81	0.92 to 3.67	0.103
Pre-eclampsia, eclampsia or HELLP					
No	117 (83.6)	196 (92.9)	1.0		
Yes	**23 (16.4)**	**15 (7.1)**	**2.86**	**1.45 to 6.08**	**0.003**
Gestational age at delivery (weeks)					
≥37	121 (85.8)	201 (95.7)	1.0		
<37	**20 (14.2)**	**9 (4.3)**	**3.99**	**1.78 to 10.84**	**<0.001**
Foetal outcomes					
Pregnancy outcome					
Live birth	137 (97.2)	209 (99.5)	1.0		
Stillbirth	4 (2.8)	1 (0.5)	3.27	0.29 to 42.7	0.214
APGAR at 1 min					
7–10	124 (87.9)	198 (94.3)	1.0		
4–6	8 (5.7)	10 (4.8)	1.19	0.57 to 4.09	0.829
<4	**9 (6.4)**	**2 (0.9)**	**8.92**	**3.38 to 62.9**	**0.004**
Birth weight (kg)					
2.5–3.9	115 (81.6)	195 (92.9)	1.0		
<2.5	**16 (11.3)**	**7 (3.3)**	**4.16**	**2.63 to 13.62**	**0.001**
≥4	10 (7.1)	8 (3.8)	2.33	0.98 to 7.34	0.093

Variables with p values lower than 0.05, considered to be significant at the 5% level, are highlighted in bold.
aOR, adjusted OR; HDU, high-dependency unit; HELLP, haemolysis, elevated liver enzymes and low platelets; ICU, intensive care unit.

which was the design of choice for the determination of vitamin D prevalence, may only establish the presence of associations of vitamin D deficiency with maternal characteristics and obstetric outcomes but is not suitable for confirming causation. Potential sources of bias were not available for analysis in the present study, such as the use of vitamin D supplements; participants were required to declare any supplements taken at admission, but the accuracy of this information was not verifiable, and according to ANC cards, many participants used different brands of supplements during the ANC period, with poor compliance during the months preceding delivery. Information about participants' diet (ie, dietary vitamin D intake) was missing, and no data were collected on participants' sunlight exposure, without consideration for the season of data collection (rainy vs sunny season). As known in the literature, there is a seasonal trend in vitamin D concentrations in temperate regions due to the variation in daily sunshine hours in distinct seasons of the year.[14] Participants were not selected based on ethnicity or skin type/

pigmentation; although women were largely black, those with other skin types were not excluded. No data were collected on participants' physical activity, which is known to be a significant independent predictor of vitamin D deficiency.[14] The sample size of the study was calculated for the determination of the prevalence of 25(OH)D deficiency among study participants; for some associations of vitamin D deficiency with adverse pregnancy outcomes, the study may not be adequately powered.

Finally, the study results may have limited external validity since this was a single-centre study conducted at a tertiary referral hospital with a significant incidence of high-risk conditions in an urban setting; therefore, the results may not be generalizable to the whole Ugandan population.

CONCLUSIONS

The study found a high prevalence (40.2%) of vitamin D deficiency among pregnant women delivering at St. Francis Hospital, Nsambya. Additionally, vitamin D deficiency was linked with adverse maternal and foetal outcomes such as hypertensive disorders in pregnancy, preterm birth and low birth weight. These findings highlight the need for increased awareness and potential interventions to address vitamin D deficiency in pregnant women to improve both maternal and neonatal outcomes.

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Patient consent for publication Not applicable.

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