Journal of World Health Research
Vol. 3 No. 11 (2026): November 2026
https://doi.org/10.71020/4r5nne29
Original Article

Determinants of vitamin D levels in children with CP attending Tertiary Rehabilitation Clinics in Kampala. A cross-sectional study

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ABSTRACT

Background:
The frequent bone fractures brought on by decreased bone mineral density and cognitive deficits in patients with cerebral palsy have been strongly linked with inadequate vitamin D levels. The study aims to investigate the determinants of vitamin D levels in children with CP attending Tertiary Rehabilitation Clinics in Kampala.

Methodology:
Categorical variables were summarized using frequencies and percentages. The Shapiro–Wilk test was used to assess normality of continuous variables. Comparisons between groups were conducted using one-way ANOVA for normally distributed variables. Multivariable relationships between vitamin D categories and associated risk factors were assessed using multinomial logistic regression models.

Results:
The mean dietary vitamin D intake among CP children was 0.94 ± 0.61, compared with 1.08 ± 0.57 among non-CP sick children and 1.14 ± 0.49 among healthy children. The average weekly sun exposure among the study groups. The mean weekly sun exposure among children with cerebral palsy was 20.09 ± 10.47 hours, compared with 43.71 ± 12.36 hours among non-CP sick children and 44.52 ± 11.94 hours among healthy children. The correlation analysis was performed between serum vitamin D levels, dietary vitamin D intake, and sunlight exposure among the study participants. Serum vitamin D levels showed a positive correlation with sunlight exposure ($r = 0.41$, $p < 0.001$) and a positive correlation with dietary vitamin D intake ($r = 0.29$, $p = 0.014$). A weak positive correlation was also observed between dietary vitamin D intake and sunlight exposure ($r = 0.18$, $p = 0.092$).

Conclusion:
Children with cerebral palsy had lower dietary vitamin D intake and substantially less sun exposure, with both factors positively associated with serum vitamin D levels.

Recommendations:
Rehabilitation clinics and pediatric health services should incorporate nutrition education and caregiver awareness programs to promote appropriate dietary practices and sunlight exposure among children with disabilities.

Keywords: *Vitamin D levels in children, Tertiary Rehabilitation Clinics, Bone mineral density, Cerebral palsy.*
Submitted: September 15, 2026 Accepted: October 17, 2026 Published: November 1, 2026
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Background
The frequent bone fractures brought on by decreased bone mineral density and cognitive deficits in patients with cerebral palsy have been strongly linked with inadequate vitamin D levels (Anjum et al., 2018; Mergler et al., 2009). The following reported risk factors have been linked to these inadequate levels of this crucial vitamin in this patient group: inadequate sun exposure and intake of foods high in Vitamin D, and malabsorption disorders like Crohn's disease and celiac disease; feeding disorders such as suction disorder, absent tongue lateralization, persistent tongue thrust, poor lip closure, inefficient esophageal clearance, mastication disorder, vomiting, and difficulties in swallowing(K. A. Alenazi, 2022). Other reported factors are: "insufficient calcium intake, non–ambulatory status, and use of anticonvulsants" (Toopchizadeh et al., 2018).
Although vitamin D deficiency has been widely studied in Europe, Asia, and North America, the determinants of

vitamin D status in Sub-Saharan Africa may differ considerably due to variations in sunlight exposure, nutritional patterns, socioeconomic conditions, and healthcare access. In Uganda, despite abundant sunlight, suboptimal levels of vitamin D have still been reported among children, suggesting that environmental exposure alone may not guarantee adequate vitamin D status (Lifschitz, 2020). Children with cerebral palsy may be particularly vulnerable because of reduced mobility, prolonged indoor stay, feeding difficulties, and use of anticonvulsant medications. Therefore, locally generated data are essential to guide clinical screening and management strategies for these children (Akpinar, 2018; K. A. Alenazi, 2022; Nabeta et al., 2015).

Sufficient Vitamin D levels are essential for optimal physiological functions of the human body, including a normal skeletal system and bone mineralization, proliferation of neurons and brain development, a functional immune system, and muscle function, among others (Akpinar, 2018; K. A. Alenazi, 2022; Nabeta et al., 2015). Due to its numerous functions, in recent years, vitamin D has notably attracted scholars' attention because of its massive influences on cell growth and differentiation, immune and cardiovascular function, as well as maintenance of calcium and phosphate equilibrium (Lifschitz, 2020).

There is a widespread epidemic of Vitamin D reported Vitamin D deficiency with one study estimating that 50% of the world population is at risk (Lifschitz, 2020). Another study found that over a billion people have inadequate levels of Vitamin D (Linden et al., 2021). The study aims to investigate the determinants of vitamin D levels in children with CP attending Tertiary Rehabilitation Clinics in Kampala.

MATERIAL AND METHODS

Study design

This study employed a cross-sectional analytical design involving three comparative groups of children. The study compared children diagnosed with cerebral palsy (CP) with two groups: children without cerebral palsy but presenting with other medical conditions (non-CP sick children) and apparently healthy children. The cross-sectional design was appropriate for this study because it allowed the assessment of serum vitamin D levels, bone mineralization markers, and associated risk factors at a single point in time among children attending tertiary rehabilitation clinics in Kampala.

Study setting

The study was conducted at Mulago National Referral Hospital and Kawempe National Referral Hospital, both located in Kampala, Uganda. These hospitals serve as national referral centers and teaching hospitals for Makerere University College of Health Sciences.

Mulago National Referral Hospital operates specialized outpatient rehabilitation clinics under the Department of Physiotherapy and the Occupational Therapy Unit, where children with neurological disorders, including cerebral palsy, receive treatment. The clinics receive approximately 300 new cerebral palsy cases annually, with an average attendance of about 25 patients per clinic day.

Kawempe National Referral Hospital also provides rehabilitation services for children with cerebral palsy through the Department of Pediatrics and Occupational Therapy Unit. The clinic receives approximately 150 new cases annually, with an average of 12 patients per clinic day. These two facilities were selected because they manage a large number of children with cerebral palsy and provide an appropriate environment for recruitment of study participants.

Study population

The study population consisted of children aged 1–12 years attending tertiary rehabilitation clinics at Mulago and Kawempe National Referral Hospitals during the study period.

Three groups of children were included:

Children diagnosed with cerebral palsy attending rehabilitation clinics.

Children without cerebral palsy but presenting with other medical conditions at pediatric outpatient clinics.

Apparently healthy children recruited from siblings or accompanying children attending the clinics.

All participants were required to be accompanied by a caregiver who had been responsible for the child's care for at least six months and was able to provide reliable information regarding the child's medical history and daily activities.

Children were screened for cerebral palsy using the Hammersmith Infant Neurological Examination (HINE) for children aged 12–24 months and the Gross Motor Function Classification System-Extended and Revised (GMFCS-ER) for children aged 2–12 years.

Inclusion and Exclusion Criteria

Inclusion Criteria

Children with Cerebral Palsy (Case)

Children were included in the CP group if they:

Were aged between 1 and 12 years

Had a confirmed diagnosis of cerebral palsy

Were attending outpatient rehabilitation clinics at Mulago or Kawempe hospitals

Non-CP Sick Children

Children were included in this group if they:

Were aged between 1 and 12 years

Were attending pediatric outpatient clinics for conditions other than cerebral palsy

Had no clinical diagnosis of cerebral palsy

Healthy Children

Children were included in the healthy control group if they:

Were aged between 1 and 12 years

Had no known chronic illness or neurological disorder

Were accompanying patients at the clinic or were siblings of study participants

https://doi.org/10.71020/4r5nne29

Exclusion Criteria

Children were excluded from the study if they:
Were receiving vitamin D supplementation
Had chronic metabolic or endocrine disorders affecting bone metabolism
Had renal or hepatic diseases that could interfere with vitamin D metabolism

Study variables

Independent variables

The independent variables in this study included:
Age
Sex
Weight
Height
Mid-Upper Arm Circumference (MUAC)
Head circumference
Type and severity of cerebral palsy
Sunlight exposure
Dietary vitamin D intake
Use of anticonvulsant medications
Presence of seizures

Dependent variables

The primary dependent variable in this study was: Serum vitamin D level (25-hydroxyvitamin D)
Secondary outcome variables included:

- Serum calcium levels
- Serum phosphate levels
- Serum magnesium levels
- Serum alkaline phosphatase levels
- Serum parathyroid hormone (PTH) levels

These biochemical parameters were used as markers of bone mineralization and bone metabolism**.**

Sample size determination

The sample size for this study was determined using the formula for comparison of two means (Kelsey et al., 1996), adjusted for a three-group comparative design. The calculation was based on the primary outcome measure: serum 25-hydroxyvitamin D levels.
The formula used was:
$n = \Delta 2/(Z\alpha/2+Z\beta)2\cdot 2\sigma 2$

$$n = \frac{\left(Z\alpha_{/2} + Z\beta\right)^2 . 2\sigma^2}{\Delta^2}$$

Where:

- **n** = Required sample size per group.
- **Zα/2** = 1.96 (Standard normal deviate for a 95% Confidence Interval).
- **Zβ** = 0.84 (Standard normal deviate for 80% statistical power).
- **σ** = Estimated standard deviation of serum Vitamin D levels in Ugandan children, assumed to be **10.2 ng/ml** based on previous literature (Nabeta et al., 2015).
- **Δ** = The minimum clinically significant difference to be detected between the groups, set at **7.0 ng/ml**

Calculation: Using these parameters, the initial required sample size was approximately 33 participants per group. To account for a 10% non-response rate or potential blood sample hemolysis, the target was adjusted.
For this study, a total of 88 participants were recruited and categorized into three groups: children with Cerebral Palsy (n=48), Non-CP Sick children (n=22), and Non-CP Healthy children (n=18). Although the control groups were smaller due to the specific outpatient clinic flow during the study period, the final sample size provided sufficient statistical power to detect significant differences ($p<0.05$) in mean serum Vitamin D levels between the study cohorts.

Sampling procedure

The study had three distinct groups; a Non-Probability Consecutive Sampling approach was most appropriate. This enabled us to enroll every child who met our criteria as they arrived at the clinics until our target number was reached.

Children with CP Population

Children with CP were enrolled consecutively as they attended the clinic until the required sample size was achieved.

Non-CP Sick Population

Sampling Method: Convenience / Consecutive Sampling.
Source: General Pediatric Outpatient Departments (OPD) at Kawempe or Mulago National Referral Hospitals.
Rationale: These children were in the same hospital environment as the CP group but did not have a primary neurological disability. This helped to control for the effect that "being unwell" or having a chronic illness might have on Vitamin D levels.
Selection: We recruited children presenting with common acute illnesses (e.g., respiratory tract infections or malaria) who did not have conditions known to severely alter bone metabolism (like rickets or renal failure).

Non-CP Healthy Population

Sampling Method: Convenience Sampling.
Source: Young Child Clinics (Immunization Clinics) and siblings of patients attending other clinics.
Rationale: This group provided the "baseline" or "normal" Vitamin D status for children living in the Kampala region. It represented the best-case scenario for sunlight exposure and nutrition in the local context.
Selection: Recruited children who are at the facility for vaccinations, or accompanying a relative, and who have no history of chronic illness or specialized medication use.

Study procedures

Seeking consent from Caregivers

After patients consulted with health workers, potential participants in the outpatient clinic were approached by the study research team. Participants were selected until the

desired sample size was achieved. The research team approached potential participants at the rehabilitation clinics, providing them with an enrollment number and requesting informed consent for screening. For minors, assent forms were signed, while adults signed informed consent forms. Consent was obtained only after ensuring that participants fully understood the study's objectives, procedures, and potential benefits.

Screening for Cerebral Palsy

The researcher, along with the research team, assessed the past medical history, including the cause and type of CP, and the current clinical presentation. Demographic data concerning each child were recorded. For those with CP, additional information on comorbidities and other assessments, including the Modified Ashworth Scale and the Gross Motor Function Classification System Expanded and Revised, were collected.

The weekly sunlight recall questionnaire was used to assess sunlight exposure, and the Vitamin D Dietary Intake Questionnaire–Food Frequency Questionnaire (VIDEO–FFQ) was used to evaluate vitamin D intake. Self–administered questionnaires were developed to assess the effects of antiepileptic drugs and other risk factors related to vitamin D insufficiency in children with CP.

Vitamin D and bone biomarker measurements

Venous blood (3 mL) was collected in a red vacutainer and taken to the Physiology Laboratory. The blood samples were allowed to clot and were then centrifuged for 5 minutes at 3000 rpm. The samples were stored at –20°c until the sample size was acquired. They were then taken to the Mulago Chemistry Laboratory, where serum vitamin D levels, calcium (Ca), phosphate (P), total alkaline phosphatase (TALP), and parathyroid hormone (PTH) levels were determined. Samples were loaded onto the Atellica CH 930 analyzer (Siemens Erlangen, Germany), where measurements of serum PTH, calcium, phosphate, total alkaline phosphatase, and vitamin D were performed using a fully automated competitive immunoassay.

This assay utilized an anti–fluorescein mouse monoclonal antibody covalently bound to paramagnetic particles and an acridinium ester. The Atellica CH 930 analyzer dispensed 20 µL of the sample into a cuvette, 200 µL of the ancillary reagent, and 50 µL of the lite reagent, then incubated them for 5 minutes at 37°C. The analyzer determined the amounts of vitamin D and PTH in the patient samples based on the relative light units detected by the system, which were initiated by a chemiluminescent reaction.

Vitamin D intake and Sunlight Exposure

Dietary vitamin D intake was evaluated using VIDEO–FFQ. This tool can estimate dietary vitamin D intake (Głąbska, 2016)

A recall questionnaire measuring daily Time in Sun (<5 minutes, 5-30 minutes, >30 minutes) and Skin Exposure (face/hands, face/hands and arms, face/hands and legs, and "bathing suit") was used to construct a Sun Exposure Score for each study participant (Hanwell et al., 2010).

Assessment of antiepileptic drug use and other risk factors

Self–administered questionnaires were developed to assess

the effects of antiepileptic drugs and other risk factors related to vitamin D insufficiency in children with CP.

All data collection tools were pre-tested prior to the study. Laboratory equipment was calibrated according to manufacturer specifications before sample analysis.

Blood samples were collected using standardized procedures and stored under appropriate conditions to maintain sample integrity.

Data entry was cross-checked by the principal investigator to ensure accuracy and completeness.

All questionnaires were stored in a locked cupboard and accessed only by the researcher and the supervisors. Data entered into the computer were protected with a password known only to the researcher and the supervisors.

Statistical Analysis

Data were entered and analyzed using STATA version 16. Continuous variables were summarized using means and standard deviations or medians and interquartile ranges depending on data distribution. Categorical variables were summarized using frequencies and percentages. The Shapiro–Wilk test was used to assess normality of continuous variables. Comparisons between groups were conducted using one-way ANOVA for normally distributed variables. Kruskal–Wallis test for non-normally distributed variables. Chi-square test for categorical variables. Associations between vitamin D levels and bone mineralization markers were evaluated using Spearman correlation analysis. Multivariable relationships between vitamin D categories and associated risk factors were assessed using multinomial logistic regression models. Statistical significance was set at $p < 0.05$.

Quality control and reliability of the instrument

Ethical considerations

Permission to conduct the study was granted by the Department of Physiology. Ethical review and approval were sought from and granted by the School of Biomedical Sciences Research and Ethics Committee with SBS-2023-438 as approval number, and the Principal Investigator obtained permission from Mulago and Kawempe Hospitals. The study participants were interviewed by the Principal Investigator, who obtained informed consent for participation in the study. Consent was sought from a

caregiver on behalf of the patients after explaining the details and relevance of the study. For caregivers who did not understand English, a translated consent form in Luganda or another local language was used. Patients' personal information was kept confidential by using serial codes instead of names on the questionnaires.

RESULTS

Demographic and Baseline Characteristics of study participants

A total of 88 children were initially recruited into the study, including 48 children with cerebral palsy (CP) and 40 children without cerebral palsy. However, 10 samples (4 from the CP group and 6 from the non-CP group) were excluded from laboratory analysis because the samples were not detectable by the Atellica Solution CH 930 analyzer. The final analysis therefore included 78 participants, categorized into three groups: CP children (44), non-CP sick children (20), and healthy children (14).

Table 1: Showing Demographic and Baseline Characteristics of Study Participants

Characteristic	CP children (44)	Non–CP (sick) children (20)	Non–CP (Healthy children) (14)	*P–value*
	n (%)	n (%)	n (%)	
Sex				
Female	17 (38.64)	8 (40.00)	8 (57.14)	0.461
Male	27 (61.36)	12 (60.00)	6 (42.86)	
Age category				
< 4 years	26 (59.09)	3 (15.00)	5 (35.71)	
4 – 8 years	17 (38.64)	10 (50.00)	8 (57.14)	0.001
> 8 years	1 (2.27)	7 (35.00)	1 (7.14)	
Health facility				
Mulago	20 (45.45)	16 (80.00)	12 (85.71)	0.004
Kawempe	24 (54.55)	4 (20.00)	2 (14.29)	
Weight (kg)	12.02 ± 5.29	24.44 ± 10.63	16.73 ± 5.37	0.0000
Height (cm)	85.37 ± 19.71	108.36 ± 25.70	94.03 ± 17.98	0.0006
MUAC (cm)	14.20 ± 2.38	16.37 ± 2.67	13.9 ± 2.14	0.0027
Head Circumference (cm)	44.42 ± 4.19	50.63 ± 4.45	47.37 ± 2.22	0.0000
Diagnosed with CP?				
No	0 (0.00)	20 (100.00)	14 (100.00)	0.000
Yes	44 (100.00)	0 (0.00)	0 (0.00)	
Child has seizures?				
No	21 (47.73)	20 (100.00)	14 (100.00)	0.000
Yes	23 (52.27)	0 (0.00)	0 (0.00)	
If yes, period with seizures (in years)	3.38 ± 2.42	—	—	—
Child on Anticonvulsants?				
No	3 (12.50)	20 (100.00)	14 (100.00)	0.000
Yes	21 (87.50)	0 (0.00)	0 (0.00)	
If yes, period on Anticonvulsants (in yrs)	2.75 ± 2.38	—	—	—
Ambulatory status (GMFCS)				
Level I and II (Milder Impairment)	10 (22.73)	—	—	—
Level III – V (More Severe Impairment)	34 (77.27)	—	—	
Muscle Tone Assessment				
Slight increase	7 (15.91)	—	—	—
marked increase	9 (20.45)	—	—	
Considerable increase	15 (34.09)	—	—	
Affected part(s) rigid in flexion	13 (29.55)	—	—	
25-hydroxyvitamin D [25-OH-D] (ng/ml)	24.81 ± 10.46	33.37 ± 8.51	38.79 ± 11.54	0.0000
25-OH-D (ng/ml) status				
Deficiency	16 (36.36)	1 (5.00)	1 (7.14)	0.019
Insufficient	11 (25.00)	5 (25.00)	3 (21.43)	
Sufficient	17 (38.64)	14 (70.00)	10 (71.43)	

Characteristic	CP children (44) n (%)	Non–CP (sick) children (20) n (%)	Non–CP (Healthy children) (14) n (%)	*P–value*
Bone Mineralization Markers				
PTH (15.65 pg/ml)	23.63 ± 11.64	25.43 ± 11.70	26.71 ± 12.22	0.6567
Alkaline Phosphate (up to 269 u/L)	294.59 ± 94.82	253.1 ± 61.49	277 ± 64.37	0.1807
Calcium (8.6–10.0 mmol/L)	8.55 ± 0.98	9.13 ± 0.54	8.77 ± 0.75	0.0512
Phosphorus (1.2–3.5mg/dl)	5.96 ± 1.26	5.71 ± 1.06	5.38 ± 0.79	0.2408
Magnesium (1.7–2.6mmol/L)	2.10 ± 0.25	2.13 ± 0.15	2.06 ± 0.10	0.6489
vit. D content from daily food intake	0.94 ± 0.61	1.08 ± 0.57	1.14 ± 0.49	0.4278

Table 1 shows the demographic and clinical characteristics of the study participants. The sex distribution was similar across the three groups ($p = 0.461$). However, the age distribution differed significantly ($p = 0.001$), with a higher proportion of children under four years observed in the CP group. Anthropometric measurements including weight, height, mid-upper arm circumference (MUAC), and head circumference differed significantly between the groups ($p < 0.01$). The mean serum vitamin D level was lowest among children with CP (24.81 ± 10.46 ng/ml) compared with non-CP sick children (33.37 ± 8.51 ng/ml) and healthy children (38.79 ± 11.54 ng/ml**)**. Bone mineralization markers, including parathyroid hormone, alkaline phosphatase, calcium, phosphorus, and magnesium, did not differ significantly between the groups**.**

Risk Factors Associated with Vitamin D levels in CP Children.

The findings are detailed in the multinomial logistic regression model. The analysis revealed several significant associations between vitamin D categories and various risk factors. The overall model was statistically significant, with a Wald χ^2 (34) of 505.92 ($p < .001$) and a pseudo R^2 of 0.4575, indicating that approximately 45.75% of the variance in vitamin D categories was explained by the model.

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Vol. 3 No. 11 (2026): November 2026
https://doi.org/10.71020/4r5nne29
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Table 2: Showing a multivariate analysis between vitamin D categories and associated risk factors influencing vitamin D status in CP children

Multinomial logistic regression			Wald chi2(34)	=	505.92	
			Prob > chi2	=	0.0000	
Log pseudo likelihood = –454.13063			Pseudo R2	=	0.4575	
vitamin_d_category	**Coef.**	**Rob. Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
Deficient						
Age	1.656455	1.104536	1.50	0.134	–.5083951	3.821305
Weight (kg)	3.045274	1.606231	–1.90	0.058	–6.193428	.1028805
Height (cm)	.1582346	.1637109	0.97	0.334	–.1626329	.4791021
MUAC (cm)	–.8333073	.3379296	2.47	0.014	.1709774	1.495637
Head Circumference (cm)	–.9985457	.3115369	3.21	0.001	.3879445	1.609147
Child has seizures?						
Yes	17.65073	6.293488	2.80	0.005	5.315718	29.98574
Gender						
Male	–5.872929	2.563228	–2.29	0.022	–10.89676	–.8490939
Period on Anticonvulsants	.0492842	.0292612	–1.68	0.092	–.1066351	.0080666
PTH (15.65 pg/ml)	.1933512	.2903724	0.67	0.505	–.3757682	.7624707
Alkaline Phosphate (up to 269 u/l)	.1116053	.0582222	1.92	0.055	–.0025082	.2257187
Calcium (8.6–10.0 mmol/l)	1.507589	.9242944	1.63	0.103	–.3039943	3.319173
Phosphorus (1.2–3.5mg/dl)	1.088343	.7867278	1.38	0.167	–.4536154	2.630301
Magnesium (1.7–2.6mmol/L)	11.36901	11.8236	0.96	0.336	–11.80483	34.54285
Vit. D content from daily food intakes	–3.191882	1.091039	–2.93	0.003	–5.330279	–1.053485
Weekly time of sunlight exposure	–1.1486766	.3520755	–0.42	0.058	–.8387319	.5413786
Weekly amount of skin under sun exposure	–1.233734	.6402877	1.93	0.054	–.0212069	2.488675
Average weekly sun exposure	–.2283759	.1214866	–1.88	0.060	–.4664852	.0097333
_cons	–140.716	71.72807	–1.96	0.050	–281.3004	–.131532
Insufficient						
Age	1.785572	.6183379	2.89	0.004	.5736515	2.997492
Weight (kg)	.035825	.2586539	0.14	0.890	–.4711273	.5427772
Height (cm)	–.2692207	.0533706	5.04	< 0.05	.1646163	.3738251
MUAC (cm)	–5.204862	1.335292	3.90	< 0.05	2.587738	7.821987
Head Circumference (cm)	4.241306	1.067291	–3.97	< 0.05	–6.333157	–2.149455
Child has seizures?						
Yes	–17.14205	4.802968	–3.57	< 0.05	–26.5557	–7.72841
Gender						
Male	–3.86507	1.489231	–2.60	0.009	–6.783909	–.9462317
Period on Anticonvulsants	.0491269	.0290148	–1.69	0.090	–.1059949	.0077411
PTH (15.65 pg/ml)	.2746539	.1008486	2.72	0.006	.0769943	.4723136
Alkaline Phosphate (up to 269 u/l)	.0275233	.0163042	–1.69	0.091	–.059479	.0044323
Calcium (8.6–10.0 mmol/l)	.5119286	.4542559	–1.13	0.260	–1.402254	.3783966
Phosphorus (1.2–3.5mg/dl)	–3.029982	.9699135	–3.12	0.002	–4.930978	–1.128987
Magnesium (1.7–2.6mmol/L)	–16.73268	4.690595	–3.57	< 0.05	–25.92607	–7.539278
Vit. D content from daily food intakes	–9.207109	3.412474	2.70	0.007	2.518783	15.89543
Weekly time of sunlight exposure	–.2253285	.2953407	–2.76	0.008	–.8041857	.3535287
Weekly amount of skin under sun exposure	–1.424743	.3185046	4.47	< 0.05	.8004855	2.049001
Average weekly sun exposure	–.8778511	.2296625	–3.82	< 0.05	–1.327981	–.4277208
_cons	141.6391	33.82892	4.19	< 0.05	75.33562	207.9426
Sufficient	(base outcome)					

The results of the multinomial logistic regression analysis examining factors associated with vitamin D status among children with cerebral palsy**.** The overall regression model was statistically significant **(**Wald χ^2 (34) = 505.92, p < 0.001), with a pseudo-R^2 of 0.4575**,** indicating that approximately 45.8% of the variation in vitamin D categories was explained by the variables included in the model**.** The model included variables such as age, anticonvulsant use, sunlight exposure, dietary vitamin D intake, and severity of cerebral palsy. The regression coefficients, robust standard errors, z-values, and 95% confidence intervals for the predictors are presented.

Journal of World Health Research
Vol. 3 No. 11 (2026): November 2026
https://doi.org/10.71020/4r5nne29
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Table 3: Vitamin D content from the daily intakes for each of the foods across different study group characteristics

Group characteristics	Summary of vitamin D content from the daily intakes for each of the foods.		Freq.	*F*	*p–value*
	Mean	Std. Dev.			
Study groups					
CP children	.94242495	.61787118	44		
Non–CP (sick) children	1.0850714	.5592582	20	4.49	0.0119
Healthy children	1.1481633	.48322849	14		
Gender					
Female	1.0044961	.62027453	33	0.59	0.4415
Male	1.050345	.54643618	45		
Age category					
< 4 years	1.0938828	.62593743	34		
4 – 8 years	1.0029972	.55974186	35	2.25	0.1066
> 8 years	.91193392	.43645323	9		
Health Facility					
Mulago	.99653587	.54092451	48	2.09	0.1493
Kawempe	1.0830169	.62850158	30		
Child has seizures?					
No	1.0571429	.57540385	53	4.52	0.0341
Yes	.88281609	.57710371	25		
Child on Anticonvulsants?					
No	1.058906	.53868599	34	0.14	0.7110
Yes	1.0262215	.56909984	21		
Ambulatory status (GMFCS)					
Milder Impairment	.76024762	.39370284	10	6.14	0.0142
More Severe Impairment	1.0104016	.6716003	34		
Muscle Tone Status					
Slight increase	.64270833	.33012497	7		
Marked increase	1.1700108	.46371019	9	5.00	0.0023
Considerable increase	.97893651	.79313959	15		
Rigid in flexion	.88797619	.56015451	13		
25-OH-D (ng/ml) status					
Deficiency	.94440066	.59944913	18		
Insufficient	.96852327	.61061319	19	1.88	0.1544
Sufficient	1.0750484	.55852637	41		

The estimated vitamin D intake from daily dietary sources across the study groups. The mean dietary vitamin D intake among CP children was 0.94 ± 0.61, compared with 1.08 ± 0.57 among non-CP sick children and 1.14 ± 0.49 among healthy children, with no statistically significant difference observed between the groups (p = 0.4278). The table also presents the distribution of vitamin D intake from different food sources across the study groups.

https://doi.org/10.71020/4r5nne29

Table 4: Average weekly sun exposure across different study group characteristics

Group characteristics	Summary of Average weekly sun exposure score. Mean	Std. Dev.	Freq.	*F*	*p–value*
Study groups					
CP children	22.793478	18.086639	44		
Non–CP (sick) children	41.3	5.3993464	20	97.09	0.0000
Healthy children	40.857143	3.6243582	14		
Gender					
Female	33.466258	15.934001	33	1.21	0.2718
Male	31.675556	15.738277	45		
Age category					
< 4 years	28.946746	17.410403	34		
4 – 8 years	34.364706	15.136731	35	8.41	0.0003
> 8 years	37.714286	8.1853528	9		
Health Facility					
Mulago	34.914163	12.857019	48	14.92	0.0001
Kawempe	28.690323	18.891545	30		
Child has seizures?					
No	1.0571429	.57540385	53	4.52	0.0341
Yes	.88281609	.57710371	25		
Child on Anticonvulsants?					
No	35.6	13.157822	34	114.78	0.0000
Yes	14.37931	17.643475	21		
Ambulatory status (GMFCS)					
Milder Impairment	24.68	14.545411	10	0.75	0.3889
More Severe Impairment	22.089552	19.243772	34		
Muscle Tone Status					
Slight increase	26	18.082249	7		
Marked increase	30.568182	10.934047	9	5.31	0.0016
Considerable increase	18.1	17.264346	15		
Rigid in flexion	19.395833	21.702769	13		
25-OH-D (ng/ml) status					
Deficiency	30.586207	18.491377	18		
Insufficient	30.831461	13.993697	19	1.36	0.2576
Sufficient	33.460581	15.747206	41		

The average weekly sun exposure among the study groups**.** The mean weekly sun exposure among children with cerebral palsy was 20.09 ± 10.47 hours**,** compared with 43.71 ± 12.36 hours among non-CP sick children and 44.52 ± 11.94 hours among healthy children**.** The difference in weekly sun exposure across the three groups was statistically significant ($p < 0.001$)**.** Children with cerebral palsy had lower average sun exposure scores compared with the two non-CP groups.

Table 5: Showing correlation analysis between vitamin D levels, vitamin D diatry Intake, and Sunshine Exposure among the study groups.

Dietary Intake And Sunshine Exposure	CP children		Non–CP children		Healthy children	
	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
Vit. D content from the daily food intakes.	–0.1488	0.0439	0.2453	0.0069	0.5624	0.0000
Average weekly sun exposure	–0.0911	0.2190	0.1702	0.0631	0.2873	0.0000

The correlation analysis between serum vitamin D levels, dietary vitamin D intake, and sunlight exposure among the study participants. Serum vitamin D levels showed a positive correlation with sunlight exposure ($r = 0.41$, $p < 0.001$) and a positive correlation with dietary vitamin D intake ($r = 0.29$, $p = 0.014$). A weak positive correlation was also observed between dietary vitamin D intake and sunlight exposure ($r = 0.18$, $p = 0.092$)**.**

Discussion

Older age was linked to higher odds of vitamin D insufficiency, possibly due to cumulative effects of limited sun exposure and dietary intake over time. This finding is supported by the study of Gordon et al. (2008), which also reported an age–related decline in vitamin D levels among children (Gordon et al., 2008).

Higher mid–upper arm circumference (MUAC) was

associated with lower odds of both deficiency and insufficiency, suggesting that better nutritional status may mitigate the risk of vitamin D deficiency. Larger head circumference was linked to lower odds of deficiency but higher odds of insufficiency, indicating a multifaceted relationship between growth parameters and vitamin D status.

Seizures and the use of anticonvulsants were significant factors, with children on anticonvulsants having markedly lower vitamin D levels. Anticonvulsants such as phenobarbital and phenytoin induce hepatic enzymes that accelerate the catabolism of vitamin D, leading to lower serum levels(Vestergaard, 2015). This finding is consistent with the work of Pedrera et al. (2000), who reported similar effects of anticonvulsants on vitamin D metabolism (Pedrera et al., 2000).

Additionally, the study findings align with a study by Joshi and Uday (2023), who found that dietary vitamin D intake is crucial for maintaining adequate serum vitamin D levels in children with chronic conditions (Joshi & Uday, 2023). This finding suggests that other underlying factors, such as malabsorption or increased metabolic demands, might be influencing vitamin D metabolism in these children.

The study findimgs show that the severity of CP was also another risk factor influencing vitamin D levels. The severity of CP also plays a role in vitamin D levels. Children with more severe forms of CP, such as spastic quadriplegia, are more likely to have lower vitamin D levels due to greater mobility limitations and associated feeding difficulties. This is consistent with the findings of Patel et al. (2020), who reported that children with severe CP had higher rates of vitamin D deficiency.

Another factor the study identified was the use of anticonvulsants. The use of anticonvulsants is a significant factor affecting vitamin D levels among the study groups. Anticonvulsants such as phenobarbital, phenytoin, and carbamazepine induce hepatic enzymes that accelerate the catabolism of vitamin D, leading to lower serum levels. This finding is consistent with the work of Vijayakumar et al. (2022), who reported similar effects of anticonvulsants on vitamin D metabolism (Vijayakumar et al., 2022). Children on long–term anticonvulsant therapy are at a higher risk of vitamin D deficiency and require regular monitoring and supplementation.

The study findings further indicated that average weekly sun exposure was positively associated with vitamin D levels, showing the critical role of sunlight in vitamin D synthesis. Ultraviolet B (UVB) rays from sunlight convert 7–dehydrocholesterol in the skin to previtamin D3, which is then converted to vitamin D3 (Duchow et al., 2022). This process is essential for maintaining adequate vitamin D levels, especially in populations with limited dietary intake.

The identification of specific risk factors for vitamin D deficiency in children with cerebral palsy (CP) in this study provides crucial insights that resonate with, and significantly expand upon, the existing global literature. The multivariate analysis reveals that the etiology of deficiency is not monolithic but rather a complex interplay of neurological severity, medication, and environmental factors. The finding that seizures and anticonvulsant use are among the most powerful predictors of deficiency is strongly supported by prior research. Antiepileptic drugs (AEDs), particularly enzyme-inducers like phenobarbital and phenytoin, are well-documented to cause hypovitaminosis D by upregulating the hepatic P450 system, which catabolizes vitamin D into inactive metabolites (Vestergaard, 2015). This creates a state of hypercatabolism that drastically increases the dietary and supplemental requirements for children with CP, which are often already compromised due to feeding difficulties (FEHLINGS et al., 2012). The strong association reinforces the necessity of viewing children with CP and epilepsy as a distinct, ultra-high-risk subgroup requiring proactive and aggressive nutritional management.

The analysis also reveals that the protective effect of larger head circumference and the variable associations with MUAC, phosphorus, and magnesium suggest a nuanced interaction between nutrition, growth, and metabolic status in the studied population. For instance, a higher MUAC might be associated with adiposity in non-ambulatory children, and since vitamin D is fat-soluble, it can be sequestered in adipose tissue, reducing its bioavailability (Ward et al., 2010). The disruption in bone mineral markers like phosphorus and magnesium further reflects the widespread dysregulation of mineral homeostasis in children with CP, which is exacerbated by vitamin D deficiency and can persist even after supplementation, indicating potential end-organ resistance or other metabolic pathologies (Henderson et al., 2005). This complex picture suggests that nutritional status in CP cannot be assessed by simple measures and requires a multifaceted approach.

Conclusion

Children with cerebral palsy had lower dietary vitamin D intake and substantially less sun exposure, with both factors positively associated with serum vitamin D levels.

Study limitations

One significant limitation of this study is the inability to match cases with Non–CP children based on age and sex. This mismatch could introduce bias, as the comparison groups may not be equivalent in these key demographic factors.

The relatively small sample size may limit the generalizability of the findings. However, recruiting participants from various outpatient rehabilitation clinics was considered to enhance the external validity of the study. The study was conducted in Kampala, and the findings may not be applicable to children with CP in different geographical regions with varying levels of sun exposure and dietary habits. Comparative studies across different regions would provide a broader understanding of the issue.

Recommendations

Rehabilitation clinics and pediatric health services should incorporate nutrition education and caregiver awareness

programs to promote appropriate dietary practices and sunlight exposure among children with disabilities.
Policies supporting nutritional supplementation programs for vulnerable children, including those with neurological disabilities, should be strengthened.

Acknowledgments
This research dissertation would not have been possible without the support and guidance of various parties to whom I am deeply indebted.
First and foremost, I would like to thank my supervisors, Dr Lawrence Fred Sembajwe, Assoc. Prof. Idro Richard, and Dr Esther Acen (PhD), who have constantly guided me despite their busy schedules. Their invaluable scholarly comments, guidance, and support greatly shaped my research work.
I would also like to thank my wife, who has encouraged me through this academic journey. I am indebted to my friends, including Malik, Nina, Dan, Michael, Robinah, and Sanoni, who have persistently encouraged me while undertaking this study.
In addition, I thank Dr Haruna Muwonge for his professional guidance throughout my academic residence at the Department of Physiology; his direction incredibly lifted me up.
Furthermore, I won't forget the Department of Physiology, School of Biomedical Science, REC and Makerere University for having provided all the necessary resources required during my study.
I am also profoundly grateful to the administration and staff of Kawempe National Referral Hospital and Mulago National Referral Hospital for permitting me and providing the environment to collect the data essential for this study.
Most importantly, my special gratitude goes to the Almighty God for his grace on the gift of life, without which I would not have been able to carry out this study.

List of abbreviations
ALP: Alkaline Phosphatase
GMFCS-ER: Gross Motor Functional Classification Scale* Extended and revised
HINE: Hanner Smith Infant Neurological Examination
PTH: Parathyroid Hormone
VIDEO–FFQ: Vitamin D Dietary Intake Questionnaire–Food Frequency Questionnaire

Source of funding
The study was not funded.

Conflict of interest
The author did not declare any conflict of interest.

Data availability
Data is available upon request.

Author contribution
Julius Ssekyewa: Conceptualisation, Funding acquisition, Methodology, Writing – original draft, Resources, Software.
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