

Serum vitamin D levels among children with Cerebral Palsy attending tertiary rehabilitation clinics in Kampala. A cross-sectional study.

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ABSTRACT

Background

Vitamin D promotes intestinal absorption of calcium and phosphate, both essential for bone mineralization and skeletal development. The study aims to determine serum vitamin D levels among children with Cerebral Palsy attending Tertiary Rehabilitation Clinics in Kampala.

Methodology

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.

Results

The age distribution differed significantly ($p = 0.001$). Mean vitamin D levels differed significantly across the study groups ($F = 11.87$, $p < 0.001$). Children with cerebral palsy had the lowest mean vitamin D levels (24.81 ng/ml) compared with non-CP sick children (33.38 ng/ml) and healthy children (38.79 ng/ml). Significant differences in vitamin D levels were also observed according to the presence of seizures ($F = 25.20$, $p < 0.001$) and use of anticonvulsant medications ($F = 49.21$, $p < 0.001$). Children receiving anticonvulsant therapy had lower mean vitamin D levels compared with those not receiving such treatment. Additionally, children with more severe motor impairment (GMFCS levels III–V) had lower mean vitamin D levels compared with those with milder impairment ($F = 5.69$, $p = 0.0217$).

Conclusion

Children with cerebral palsy had significantly lower vitamin D levels than non-CP sick and healthy children. Low vitamin D levels were particularly associated with seizures, anticonvulsant use, and severe motor impairment. Routine vitamin D assessment should therefore be considered in children with cerebral palsy, especially those with these risk factors.

Recommendations

Healthcare providers managing children with cerebral palsy should consider routine screening for serum vitamin D levels, particularly among children with severe motor impairment or those receiving anticonvulsant medications.

Keywords: Serum vitamin D levels, Children with Cerebral Palsy, Tertiary Rehabilitation clinics in Kampala.

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Background

Vitamin D is a fat-soluble prohormone that plays a critical role in calcium homeostasis and bone metabolism (Bikle, 2016). It exists in two major forms: vitamin D₂ (ergocalciferol), which is derived from plant sources, and vitamin D₃ (cholecalciferol), which is synthesized in the skin following exposure to ultraviolet B (UVB) radiation

from sunlight (Beto, 2015).

Following synthesis in the skin or ingestion from dietary sources, vitamin D undergoes two hydroxylation steps before becoming biologically active. The first hydroxylation occurs in the liver, where vitamin D is converted into 25-hydroxyvitamin D [25(OH)D], the main circulating form used to determine vitamin D status (Christakos et al., 2016).

The second hydroxylation occurs primarily in the kidneys, where 25(OH)D is converted into its active hormonal form, 1,25-dihydroxyvitamin D [1,25(OH)₂D], through the action of the enzyme 1-alpha-hydroxylase (CYP27B1) (Bikle, 2016).

The kidneys therefore play a crucial role in regulating vitamin D activity by converting circulating vitamin D metabolites into their biologically active form (Christakos et al., 2016). The active form of vitamin D exerts its physiological effects by binding to vitamin D receptors (VDRs), which are widely distributed in many tissues including bone, intestine, kidney, and immune cells (Bikle, 2016).

Vitamin D promotes intestinal absorption of calcium and phosphate, both essential for bone mineralization and skeletal development (Beto, 2015). Deficiency of vitamin D may therefore result in impaired bone mineralization, reduced bone mineral density, and increased risk of fractures (Lifschitz, 2020).

Globally, vitamin D deficiency has become a significant public health problem, with estimates suggesting that over one billion people worldwide have insufficient vitamin D levels (Linden et al., 2021). Although vitamin D deficiency is traditionally associated with regions with limited sunlight exposure, studies have shown that it can also occur in tropical regions, including Sub-Saharan Africa (Nabeta et al., 2015). The study aims to determine serum vitamin D levels among children with Cerebral Palsy 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 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

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 =

Where:

- **n** = Required sample size per group.
- **Z α /2** = 1.96 (Standard normal deviate for a 95%

Confidence Interval).

- **Z β** = 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 (Immunisation 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 analyser (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 utilised an anti-fluorescein mouse monoclonal

antibody covalently bound to paramagnetic particles and an acridinium ester. The Atellica CH 930 analyser 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 analyser 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 (Głowska, 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 of the study participants (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.

Statistical Analysis

Data were entered and analysed using STATA version 16. Continuous variables were summarised using means and standard deviations or medians and interquartile ranges depending on data distribution. Categorical variables were summarised 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 was used for non-normally distributed variables. Chi-square test for categorical variables. Associations between vitamin D levels and bone mineralisation 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

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

Blood samples were collected using standardised 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.

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.

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 the 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

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: Demographic and Baseline Characteristics of Study Participants

Characteristic	CP children (44) n (%)	Non-CP children (20) n (%)	(sick) Non-CP (Healthy children) (14) n (%)	P-value
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)	0.001
4 – 8 years	17 (38.64)	10 (50.00)	8 (57.14)	
> 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)				

Characteristic	CP children (44) n (%)	Non-CP children (20) n (%)	(sick)	Non-CP (Healthy children) (14) n (%)	P-value
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)	
Insufficient	11 (25.00)	5 (25.00)		3 (21.43)	0.019
Sufficient	17 (38.64)	14 (70.00)		10 (71.43)	
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.

Table 2: Serum Vitamin D levels across different study group characteristics

Group characteristics	Summary of Vitamin D (ng/ml)		Freq.	F	p-value
	Mean	Std. Dev.			
Study groups					
CP children	24.812045	10.468917	44		
Non-CP children	33.378	8.5135537	20	11.87	0.0000
Healthy children	38.791429	11.548752	14		
Gender					
Female	28.892424	11.902461	33	0.17	0.6855
Male	29.976	11.425979	45		
Age category					
< 4 years	28.233235	13.019812	34		
4 – 8 years	30.770571	10.744582	35	0.41	0.6660
> 8 years	29.496667	9.1505792	9		
Health Facility					
Mulago	30.116875	11.620684	48	0.33	0.5661

Group characteristics	Summary of Vitamin D (ng/ml)		Freq.	F	p-value
	Mean	Std. Dev.			
Kawempe	28.558667	11.609094	30		
Diagnosed with CP?					
No	35.607059	10.07897	34	21.06	0.0000
Yes	24.812045	10.468917	44		
Child has seizures?					
No	33.455849	10.812024	53	25.20	0.0000
Yes	21.1684	8.3079754	25		
Child on Anticonvulsants?					
No	36.442647	9.4787463	34	49.21	0.0000
Yes	19.68619	6.9304	21		
Ambulatory status (GMFCS)					
Milder Impairment	31.403	8.4501703	10	5.69	0.0217
More Severe Impairment	22.873529	10.310191	34		
Muscle Tone Status					
Slight increase	31.94	7.3804742	7	1.99	0.1312
marked increase	26.481111	8.1195527	9		
Considerable increase	24.070667	11.701243	15		
Rigid in flexion	20.673846	10.527817	13		
25-OH-D (ng/ml) status					
Deficiency	14.045	3.6675689	18	160.98	0.0000
Insufficient	24.210526	3.0008896	19		
Sufficient	38.769756	6.2354982	41		

Table 2 presents the distribution of serum vitamin D levels across demographic and clinical characteristics of the study participants. Mean vitamin D levels differed significantly across the study groups ($F = 11.87$, $p < 0.001$). Children with cerebral palsy had the lowest mean vitamin D levels (24.81 ng/ml) compared with non-CP sick children (33.38 ng/ml) and healthy children (38.79 ng/ml). Significant differences in vitamin D levels were also observed according to the presence of seizures ($F = 25.20$, p

< 0.001) and use of anticonvulsant medications ($F = 49.21$, $p < 0.001$). Children receiving anticonvulsant therapy had lower mean vitamin D levels compared with those not receiving such treatment. Additionally, children with more severe motor impairment (GMFCS levels III–V) had lower mean vitamin D levels compared with those with milder impairment ($F = 5.69$, $p = 0.0217$). No statistically significant differences were observed in vitamin D levels across sex, age categories, or health facility.

Table 3: Interquartile ranges of serum 25–Hydroxyvitamin D by study groups

Study groups	Summary of Vitamin D (ng/ml)					F	P-value
	n	p25	p50	p75	iqr		
CP children	44	15.415	24.02	33.93	18.515	11.87	0.0000
Non-CP (sick) children	20	27.585	34.335	38.775	11.19		
Healthy	14	27.8	42.47	46.72	18.92		
Total	78	20.1	30.375	38.7	18.6		

From Table 3: The distribution of serum vitamin D levels across the study groups is presented in Table 3 using quartile statistics. The median vitamin D level (p50) was lowest among children with cerebral palsy (24.02 ng/ml) compared with non-CP sick children (34.34 ng/ml) and healthy children (42.47 ng/ml). The difference in vitamin D levels across the three groups was statistically significant ($F = 11.87$, $p < 0.001$).

The interquartile range (IQR) of vitamin D levels was 18.52 ng/ml among children with CP, 11.19 ng/ml among non-CP sick children, and 18.92 ng/ml among healthy children. The overall median vitamin D level among all study participants was 30.38 ng/ml with an interquartile range of 18.6 ng/ml. The box plot graph compares serum 25–hydroxyvitamin D levels among Non-CP (healthy), Non-CP (Sick), and CP children.

Figure 1: Comparison of serum 25-Hydroxyvitamin D levels among Non-CP (healthy), Non-CP (Sick), and CP children.

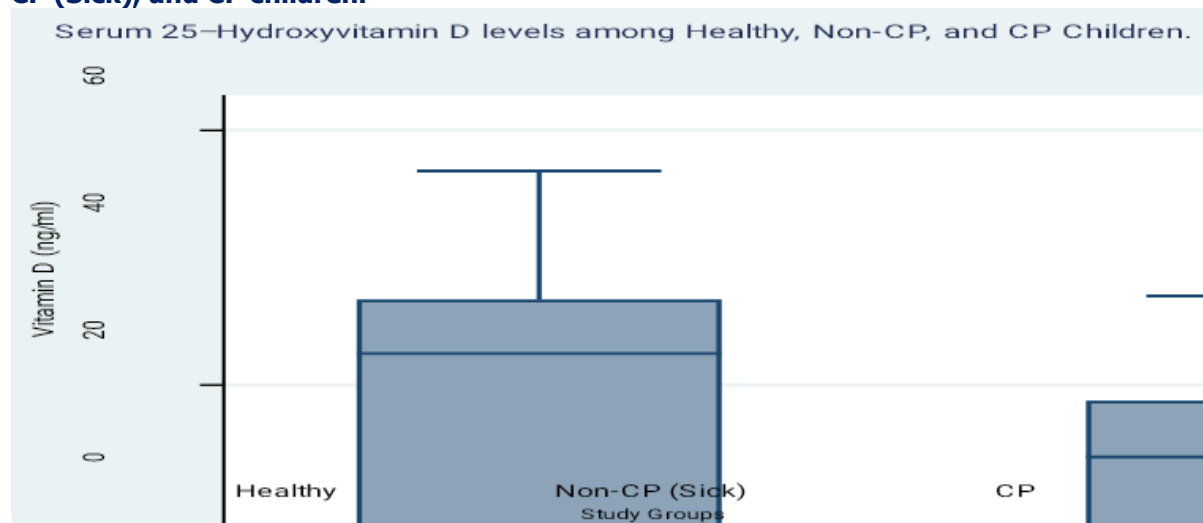


Figure 1, a box plot visually representing the distribution of serum Vitamin D levels, powerfully reinforces the quantitative findings from Table 2. The graph clearly illustrates the progressive decline in median Vitamin D levels (the central line within each box) from the Healthy group to the Non-CP (Sick) group, and finally to the CP group, which has the lowest median. Furthermore, the plot provides an immediate visual confirmation of the interquartile range (IQR) data; the box for the CP children is both positioned lower and is notably wider than the others, indicating greater variability and a broader range of values from the 25th to the 75th percentile. The whiskers, extending to the 5th and 95th percentiles, show that the CP group has a longer "tail" of very low values, representing children with severe deficiencies.

Discussion

The study revealed that children with cerebral palsy (CP) attending outpatient rehabilitation clinics in Kampala had significantly lower serum vitamin D levels compared to the control group with the mean average for Vitamin D level for the entire cohort was approximately 29.5 ng/ml. Furthermore, a significant proportion of children with CP had deficient/insufficient levels of vitamin D. These findings are consistent with previous studies, such as the study by Holick (2006) and that by Alenazi and Alanezi (2024), which reported a high prevalence of vitamin D deficiency among children with CP due to factors like limited sun exposure and dietary insufficiencies (Alenazi & Alanezi, 2024). Vitamin D is crucial for calcium absorption in the intestines, and its deficiency can lead to hypocalcemia, which in turn stimulates the release of

parathyroid hormone (PTH). PTH acts to increase calcium levels by promoting calcium release from bones, increasing calcium reabsorption in the kidneys, and enhancing the activation of vitamin D in the kidneys. This physiological response emphasises the importance of maintaining adequate vitamin D levels to prevent secondary hyperparathyroidism and associated bone demineralisation. This shows that vitamin D is crucial for bone health, immune function, and overall growth and development. Its deficiency can lead to various complications, including rickets, osteomalacia, and increased susceptibility to fractures and infections. The lower levels observed in children with CP can be attributed to several factors, including limited sun exposure, dietary insufficiencies, and the use of anticonvulsants, which have been found to interfere with vitamin D metabolism (Fragale et al., 2019). The significantly lower levels of serum Vitamin D observed in children with Cerebral Palsy (CP) compared to both sick and healthy control groups in this study align consistently with the global body of evidence on this subject. Several studies such as (Akpinar, 2018; Alenazi, 2021; Alenazi & Alanezi, 2024) have established a high prevalence of Vitamin D deficiency in this population, with prevalence rates often exceeding 80% in some cohorts, a phenomenon attributed to a confluence of factors (Alenazi & Alanezi, 2024) such as limited ambulation leading to profoundly reduced sun exposure, feeding difficulties resulting in inadequate dietary intake, and potential alterations in drug metabolism, (Kumar et al., 2022).

The finding that Vitamin D levels were remarkably lower among children with seizures and children on anticonvulsant medication is important and underpins the well-documented role of certain antiepileptic drugs (e.g., phenobarbital,

phenytoin) in accelerating the catabolism of Vitamin D through the induction of hepatic p450 enzymes, effectively creating a state of heightened nutritional requirement that is often unmet (Vestergaard, 2015). The strong interconnection between greater motor impairment (GMFCS Levels III-V) and lower Vitamin D levels further fortifies the model that functional mobility is a key antecedent of sun exposure, a primary source of Vitamin D synthesis (Henderson et al., 2002).

These findings generally suggest that children with CP, particularly those with comorbid seizures that require anticonvulsants and those children with severe motor limitations, constitute a high-risk group for whom proper screening and proactive supplementation are important (Apkon & Kecskemethy, 2008). The standard nutritional guidelines for the general pediatric population are not well implemented for this vulnerable group. Therefore, proper monitoring and integrating routine Vitamin D status assessment into the standard of care for CP and developing CP-specific supplementation protocols must be a priority (Akpinar, 2018).

Conclusion

Children with cerebral palsy had significantly lower vitamin D levels than non-CP sick and healthy children. Low vitamin D levels were particularly associated with seizures, anticonvulsant use, and severe motor impairment. Routine vitamin D assessment should therefore be considered in children with cerebral palsy, especially those with these risk factors.

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

Healthcare providers managing children with cerebral palsy should consider routine screening for serum vitamin D levels, particularly among children with severe motor impairment or those receiving anticonvulsant medications. Vitamin D supplementation and nutritional support should

be considered for children with cerebral palsy who are found to have vitamin D deficiency or insufficient dietary intake.

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List of abbreviations

GMFC: Gross Motor Functional Scale

HINE: Hanner Smith Infant Neurological Examination

PTH: Parathyroid Hormone

VDR: Vitamin D Receptors

VIDEO-FFQ: Vitamin D Dietary Intake Questionnaire–Food Frequency Questionnaire

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Conflict of interest

The author did not declare any conflict of interest.

Data availability

Data are available upon request.

Author contribution

Julius Ssekyewa: Conceptualisation, Funding acquisition, Methodology, Writing – original draft, Resources, Software. Dr Lawrence Fred Sembajwe: Software, Supervision, Validation, Visualisation, Data curation, Formal analysis, Investigation

Assoc. Prof. Idro Richard: Writing – review & editing

Dr Esther Acen: Writing – review & editing

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