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Prevalence and predictors of vitamin D insufficiency in Brazilian children under 5 years of age: Brazilian National Survey on Child Nutrition (ENANI-2019)

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Abstract

To analyse the association of socio-demographic and health factors with vitamin D insufficiency and 25-hydroxyvitamin D (25(OH)D) concentration in Brazilian children aged 6–59 months. Data from 8145 children from the Brazilian National Survey on Child Nutrition (ENANI-2019) were analysed. The serum concentration of 25(OHD)D was measured using a chemiluminescent immunoassay. The prevalence of vitamin D insufficiency (25(OH)D < 50 nmol/l) and 95 % CI was calculated. Logistic and linear regression models were used to identify the variables associated with vitamin D insufficiency and serum 25(OH)D concentrations, respectively. The mean 25(OH)D concentration was 98·6 ± 36·0 nmol/l, and 4·3 % of the children presented vitamin D insufficiency. Children aged 6–23 months (OR = 2·23; 95 % CI 1·52, 3·26); belonging to Southeast (OR = 5·55; 95 % CI 2·34, 13·17) and South (OR = 4·57; 95 % CI 1·77, 11·84) regions; the second tertile of the National Wealth Score (OR = 2·14; 95 % CI 1·16, 3·91) and winter (OR = 5·82; 95 % CI 2·67, 12·71) and spring (OR = 4·84; 95 % CI 2·17, 10·80) seasons of blood collection were associated with a higher chance of vitamin D insufficiency. Female sex ($\beta = -5·66$, 95 % CI − 7·81, −3·51), urban location ($\beta = -14·19$, 95 % CI −21·0, −7·22) and no vitamin D supplement use ($\beta = -6·01$, 95 % CI −9·64, −2·39) were inversely associated with serum 25(OH)D concentration. The age of children and the Brazilian geographical region of household location were the main predictors of vitamin D insufficiency. In Brazil, vitamin D insufficiency among children aged 6–59 months is low and is not a relevant public health problem.

Keywords: 25(OH)D: Micronutrient deficiencies: National survey: Children: Brazil

Vitamin D plays an essential role in human metabolism. Its best-known functions are calcium homoeostasis, bone mineralisation and promoting intestinal absorption of Ca and phosphorous[1]. The primary source of vitamin D is cutaneous synthesis through exposure to ultraviolet B (UVB) radiation. It can also be obtained from the diet as a relatively minor source and vitamin D supplements[2]. Given children's fast growth, inadequate vitamin D status is associated with childhood rickets[1] and other non-skeletal diseases[3].

Vitamin D insufficiency (25-hydroxyvitamin D (25(OH)D), serum concentration < 50 nmol/l or 20 ng/ml) has been discussed as a public health problem worldwide in all life cycles[4,5]. Nationally representative estimates of vitamin D insufficiency in children aged < 5 years have been reported as 6·6 % in the USA[6], 39·4 % (1 to < 2 years), 25·8 % (2 to < 5 years) in Colombia[7] and 25·9 % in Mexico[8]. In Brazil, local studies conducted including children aged < 5 years reported a high prevalence of vitamin D insufficiency, ranging from 13·6 % to 68·2 %[9,10], with results that vary depending on factors such as skin colour/race, socio-economic status, body composition, sun exposure and diet.

No nationally representative evidence on children's vitamin D status and its associated factors is available in Brazil, a tropical middle-income country with substantial regional and socio-economic disparities in health. Therefore, the present study aimed to describe the association of socio-demographic and health factors with vitamin D insufficiency and serum 25(OH)D concentration in a nationally representative sample of Brazilian children aged 6–59 months.

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; ENANI-2019, Brazilian National Survey on Child Nutrition; NWS, National Wealth Score; UVB, ultraviolet B.

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Methods

Study design and participants

The Brazilian National Survey on Child Nutrition (ENANI-2019) is a population-based household survey with national coverage and representatives of children aged < 5 years. The ENANI-2019 sample was calculated as 15 000 households in 123 municipalities and twenty-six states and the Federal District. A sample size of 3000 households per Brazilian geographical region was defined, considering a minimum proportion of 2 %, a relative error estimate of 35 %, a confidence level of 95 % and a sampling and design effect set at 2. Details of the sample design, study completion and reasons for not drawing blood samples have been published previously[11–13].

The ENANI-2019 included a probability sample of 12 524 households, and 14 558 children were studied. Among them, 12 598 children aged 6–59 months were considered eligible for drawing blood samples, and 8829 (70·1 %) had their blood samples effectively drawn (Fig. 1). In the present study, the subset consisted of all children with serum 25(OH)D test results (*n* 8217). Children who lacked information on BMI-for-age (BMI/age) (*n* 15) and those classified as Yellow (Asian origin according to the Brazilian National Institute of Geography, e.g. Japanese, Chinese and Korean) or indigenous race/skin colour (*n* 57) were excluded. Finally, this study included 8145 children aged 6–59 months. Yellow and indigenous children were excluded from the analysis owing to their small sample size, leading to low-precision estimates (Fig. 1).

Blood sample collection and 25-hydroxyvitamin D assessment

Details of the procedures adopted for blood collection and laboratory analyses have been previously described[13]. Briefly, blood samples were collected (fasting was not required), and serum was separated and stored at freezing temperature (–20°C) until laboratory analyses were performed. The serum 25(OH)D concentration was determined using a chemiluminescence immunoassay (DxI 800, Beckman Coulter, Brea). To comply with international practices[14], the method's performance in determining vitamin D concentrations was evaluated using an assay validated by the Vitamin D External Quality Assessment Scheme (http://www.deqas.org/). The validation performance was within the recommended value for the DEQAS certification (within ± 19 % of the target value). Vitamin D insufficiency was defined as a serum 25(OH)D concentration < 50 nmol/l[15].

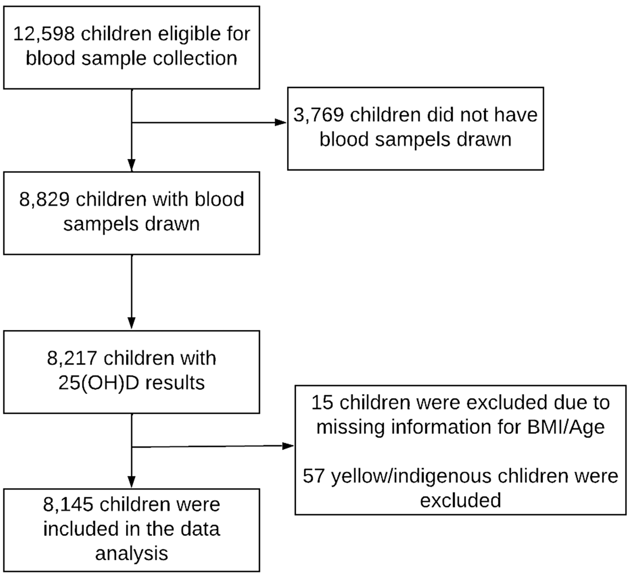

Fig. 1. Data collection flow chart, ENANI-2019.

Socio-demographic and health data collection

Trained interviewers used a structured questionnaire to collect socio-demographic and health data[12]. The variables used in this study were Brazilian geographic region (North-latitude: 02:49:12; -10:52:55; Northeast-latitude: -2:31:48; -12:58:15; Southeast-latitude: -16:44:06; -23:57:46; South-latitude: -23:25:30; -32:02:06 and Midwest-latitude: -13:03:00; -22:13:58), household location (urban or rural area), child's age (6–23/24–59 months), sex, skin colour/race (black, brown and white, from self-reported data provided by the mother/caregiver, according to the criteria established by the Brazilian National Institute of Geography and Statistics), educational level of the mother/caregiver of the child (0–7, 8–10 and ≥ 11 completed years of education) and the National Wealth Score (NWS) (in tertiles). The NWS is a synthetic household index that is used to assess the socio-economic conditions of the population and incorporates items related to the possession of consumer goods, household characteristics and the education of the head of the household (e.g. the number of bedrooms and bathrooms, presence of telephone lines and computers and presence of home Internet in the household). ENANI-2019 updated the calculation of this index[16].

The questionnaire also contained information on vitamin D supplements use considering the use at the time of the study and the previous 6 months (yes/no) and the season of blood collection in the southern hemisphere (spring (September–November), summer (December–February), autumn (March–May) and winter (June–August)). Body weight (kg) and length or height (m) were used to calculate the BMI for age (BMI/A, kg/m^2). Excess weight was defined as a BMI Z-score > +2[17,18].

Statistical analyses

The analyses were carried out by incorporating the complex sample design of the study using R programming language packages (*srvyr* and *survey)*[19]. Adjustment of basic sample weights was used considering predictor variables for non-response (absence of laboratory results for 25(OH)D) using post-stratification[20]. The descriptive analysis estimated the relative frequencies of socio-demographic and health variables, mean serum 25(OH)D concentrations, standard deviation (SD), coefficient of variation (CV) of the estimates, the prevalence of vitamin D insufficiency, and 95% confidence intervals (95% CIs). We reported the estimated results for Brazil and according to the categories of each socio-demographic and health variable, selected based on published evidence of their associations with serum 25(OH)D concentrations[1,21,22]. Estimates with a high CV may indicate that the sample was insufficient to make a population-level estimate with acceptable precision. A CV < 30 % was considered to have an appropriate level of precision for the estimates produced in the ENANI-2019. We assumed that the lack of overlap in the 95 % CI of the point estimates indicated a statistically significant difference.

A multiple logistic model was estimated having socio-demographic and health variables as exposure and vitamin D insufficiency (< 50 nmol/l) as the outcome. A multiple linear regression model was performed having the same socio-demographic and health variables as exposure and serum 25(OH)D concentrations as the outcome. The same set of confounders were used to adjust both models. These variables were selected based on a *P* value < 0·20 in the bivariate analysis.

Ethical aspects

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving research study participants were approved by the Research Ethics Committee of Clementino Fraga Filho University Hospital of UFRJ (Protocol number: 89798718.7.0000.5257). Data were collected after the child's parents or caregivers agreed to participate in the survey and signed two copies of the informed consent form, freely and spontaneously, after being provided with an explanation of all ethical issues of the study.

Results

Children were predominantly aged 24–59 months (66·7 %) and lived in urban areas (96·6 %) and the Southeast regions (39·4 %). Most mothers/caregivers had received at least 11 years of education (54·0 %). The prevalence of excess weight was 9·6 %, and vitamin D supplements were used by 21·1 % of the study population. No statistically significant differences were observed between the frequencies of blood collection according to the season (Table 1).

Table 1. Descriptive characteristics of children aged 6–59 months, ENANI-2019

Variables	Frequency (%)	95 % CI
Child age (months)		
6–23	33·3	33·0, 33·5
24–59	66·7	66·5, 67·0
Child sex		
Male	50·9	50·7, 51·2
Female	49·1	48·8, 49·3
Brazilian geographical region		
North	10·9	10·8, 11·0
Northeast	27·9	27·6, 28·2
Southeast	39·4	39·2, 39·6
South	13·6	13·5, 13·6
Midwest	8·3	8·2, 8·3
Household location		
Urban	96·6	94·4, 98·8
Rural	3·4*	1·2, 5·6
National Wealth Score (tertiles)		
1°	32·2	29·8, 34·6
2°	34·7	32·3, 37·0
3°	33·1	30·1, 36·2
Educational level of the mother/caregiver (completed years)		
0–7	23·6	21·4, 25·8
8–10	22·4	20·1, 24·6
≥11	54·0	51·1, 56·9
Skin colour/race of the child		
White	40·5	37·6, 43·4
Brown	52·6	49·6, 55·7
Black	6·9	5·7, 8·1
Excess weight (Z BMI > +2)		
No	90·4	88·9, 91·9
Yes	9·6	8·1, 11·1
Vitamin D supplement use		
Yes	21·1	17·9, 24·3
No	78·9	75·7, 82·1
Season of blood collection		
Summer (December–February)	19·2	13·8, 24·5
Autumn (March–May)	32·4	23·3, 41·8
Winter (June–August)	22·8	18·4, 27·2
Spring (September–November)	25·6	17·9, 33·3

Z BMI, body mass index Z-score.
* CV values higher than 30% show a low estimate precision.

The serum 25(OH)D concentration distribution curve was skewed, with an elongated tail on the right side (Fig. 2). Children from the South, Southeast and Midwest regions, who lived in an urban area, aged 24–59 months and whose blood collection was performed in winter and spring seasons, presented curves shifted to the left than those of children from other regions, who lived in rural areas, aged between 6-23 months and whose blood collection was performed in summer and autumn seasons (Fig. 2).

The mean serum 25(OH)D concentration was 98·6 nmol/l (SD = 36·0), and 4·3 % of the children presented with vitamin D insufficiency (Table 2). The prevalence of vitamin D insufficiency was higher in children aged 24–59 months (5·4 %) than that in those aged 6–23 months (2·3 %); children who lived in the South and Southeast regions (7·8 % and 6·9 %, respectively) than that in those from North and Northeast regions (1·2 % and 0·9 %, respectively); children who lived in urban areas (4·4 %) than that in those who lived in rural areas (1·8 %); children with white skin colour/race (6·6 %) than that in those with brown (2·9 %) and black (2·3 %) skin colour/race and among children in whom blood was collected in winter (7·4 %) and spring (6·9 %) seasons than that in those in whom blood was collected in summer season (0·9 %). No statistically significant differences in the prevalence of vitamin D insufficiency were observed among the categories of NWS, educational level of the mother/caregiver, child sex, BMI Z-score and vitamin D supplement use (Table 2).

In the multiple logistic regression model, it was observed a higher chance of vitamin D insufficiency in children aged 24–59 months (OR = 2·23; 95 % CI 1·52, 3·27) than that in those aged 6–23 months; children living in Southeast (OR = 5·55; 95 % CI 2·34, 13·16) and South (OR = 4·57; 95 % CI 1·77, 11·83) regions than that in those living in Northeast regions; children belonging to the second tertile of NWS (OR = 2·14; 95 % CI 1·17, 3·91) than that of those belonging to the third tertile of NWS; children in whom blood was collected in winter (OR = 5·82; 95 % CI 2·66, 12·72) and spring (OR = 4·84; 95 % CI 2·17, 10·80) seasons than that in those in whom blood was collected in summer season and

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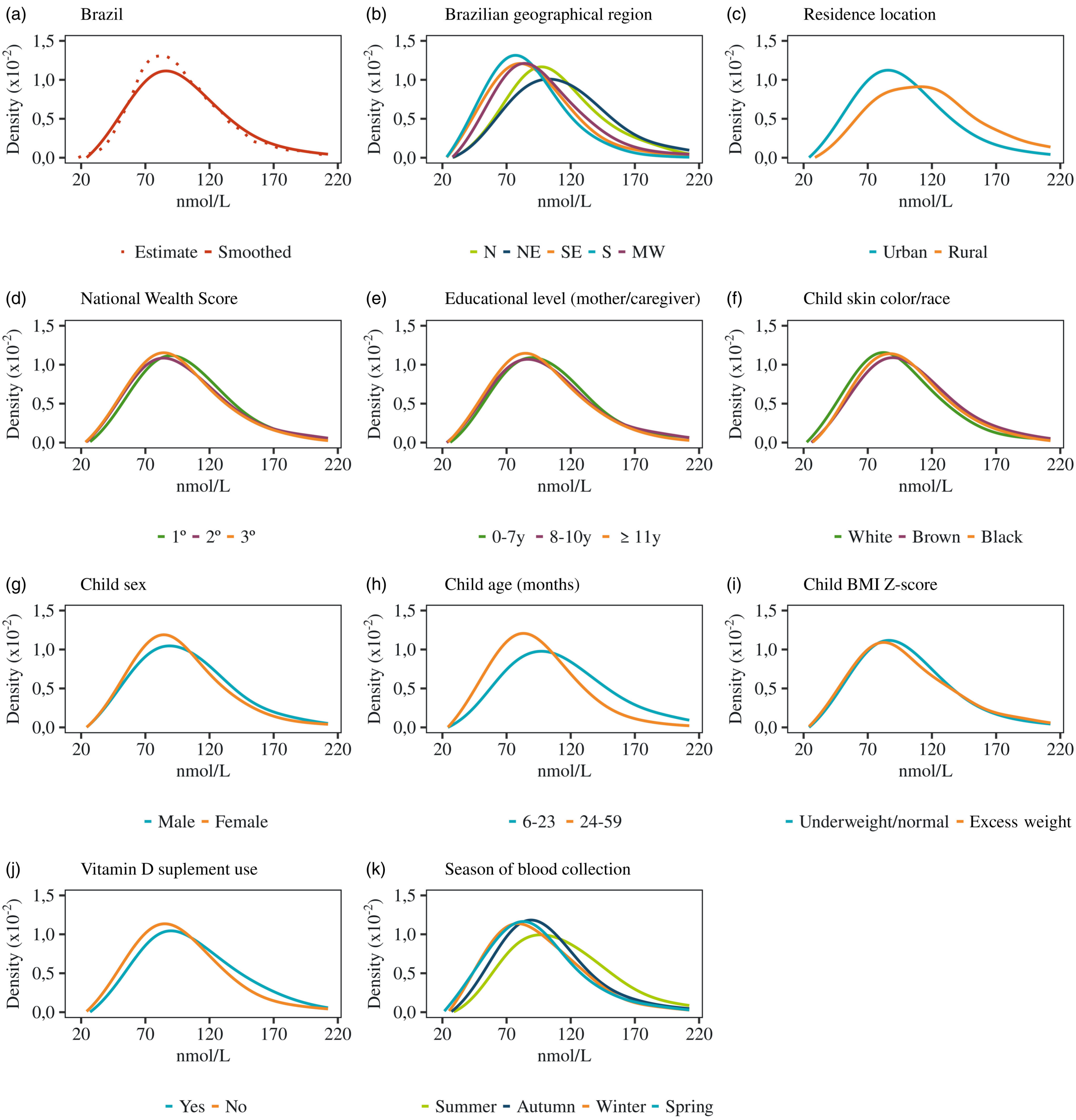

Fig. 2. Density curves of serum 25-hydroxyvitamin D (25(OH)D) concentrations among children aged 6–59 months according to socio-demographic and health variables, ENANI-2019. Notes: N, North; NE, Northeast; SE, Southeast; S, South; MW, Midwest; BMI Z-score, body mass index Z-score. The x-axis is truncated to the right at the 99th percentile (211·4 nmol/l). Smoothing method: local polynomial regression via kernel (bandwidth = 18).

those with white skin colour/race than that in those with brown (OR = 0·61; 95 % CI 0·38, 0·98) and black (OR = 0·44; 95 % CI 0·21, 0·93) skin colour/race (Table 3).

In the multiple linear regression model, the mother/caregiver's educational level of 0–7 years (β = 4·33; 95 % CI 0·96, 7·69) was positively associated with serum 25(OH)D concentration (≥ 11 years educational level as a reference). Female sex (β = −5·66; 95 % CI −7·81, −3·51), urban location (β = −14·19; 95 % CI −20·69, −7·68), and no vitamin D supplement use (β = −6·01; 95 % CI −9·64, −2·39) were inversely associated with serum 25(OH)D concentration (Table 4).

Discussion

In this nationally representative survey in a large and tropical middle-income country, the prevalence of vitamin D insufficiency among children aged 6–59 months was low (4·3 %) and,

Table 2. Prevalence of vitamin D insufficiency according to socio-demographic and health variables in Brazilian children aged 6–59 months, ENANI-2019

Variables	Serum 25(OH)D concentration				
	Mean (nmol/l)	SD	95 % CI	Prevalence (%) of insufficiency (<50 nmol/l)	95 % CI
Brazil	98·6	36·0	96·2, 101·1	4·3	2·9, 5·8
Child age (months)					
6–23	112·0	41·1	108·1, 115·8	2·3	1·3, 3·3
24–59	92·0	31·1	89·5, 94·4	5·4	3·5, 7·2
Child sex					
Male	101·4	37·4	98·6, 104·2	4·4	2·8, 6·0
Female	95·8	34·3	93·1, 98·4	4·3	2·8, 5·8
Brazilian geographical region					
North	108·9	34·0	102·6, 115·1	1·2*	0·1, 2·3
Northeast	115·0	38·8	110·7, 119·4	0·9*	0·2, 1·5
Southeast	89·4	31·7	84·5, 94·4	6·9	3·5, 10·3
South	84·2	28·1	81·7, 86·6	7·8	4·6, 11·1
Midwest	97·5	34·9	93·7, 101·2	2·2	1·2, 3·2
Household location					
Urban	98·0	35·7	95·5, 100·4	4·4	3·0, 5·9
Rural	117·4	40·1	108·7, 126·2	1·8*	0·0, 4·0
National Wealth Score (tertiles)					
1°	102·3	36·7	100·4, 104·2	2·7	1·9, 3·5
2°	98·7	37·4	95·4, 102·1	5·6	3·5, 7·7
3°	95·0	33·5	90·7, 99·3	4·6	2·0, 7·3
Educational level of the mother/caregiver (completed years)					
0–7	102·5	37·1	99·6, 105·5	2·7	1·2, 4·2
8–10	100·5	38·3	96·1, 104·9	4·6	2·7, 6·4
≥11	96·2	34·3	93·3, 99·0	5·0	3·3, 6·7
Skin colour/race of child					
White	93·6	35·1	90·7, 96·4	6·6	4·4, 8·8
Brown	102·3	36·1	99·5, 105·1	2·9	1·6, 4·2
Black	100·1	37·1	94·0, 106·2	2·3*	0·7, 4·0
Excess weight (Z BMI > +2)					
No	98·6	35·7	96·0, 101·2	4·3	2·8, 5·8
Yes	98·9	38·9	92·7, 105·1	5·1	2·4, 7·8
Vitamin D supplement use					
Yes	106·4	37·8	101·9, 110·8	2·6*	0·9, 4·3
No	96·6	35·2	93·8, 99·3	4·8	3·0, 6·6
Season of blood collection					
Summer (December–February)	113·1	39·2	107·9, 118·2	0·9*	0·3, 1·5
Autumn (March–May)	100·2	34·8	94·7, 105·8	2·2	1·2, 3·3
Winter (June–August)	91·6	34·2	87·5, 95·7	7·4	5·0, 9·9
Spring (September–November)	92·0	33·2	86·7, 97·4	6·9	3·3, 10·4

Z BMI, body mass index Z-score.
* CV values higher than 30% show a low estimate precision.

therefore, did not constitute a public health problem. Nevertheless, a higher chance of vitamin D insufficiency was observed in children aged 24–59 months, those who lived in regions with higher latitudes in the southern regions and those who participated in the study during the winter and spring seasons.

Representative surveys performed in other Latin American countries in children aged < 5 years reported a higher prevalence of vitamin D insufficiency. The Mexican National Health and Nutrition Survey (2012) reported a 25·9 % prevalence of vitamin D insufficiency in preschoolers (1–4 years)[8]. In the Colombian National Nutrition Survey (2015), the prevalence was 27·7 % in preschoolers (2–4 years) and 42·5 % in toddlers (1 to < 2 years)[7]. The prevalence of vitamin D insufficiency observed in the ENANI-2019 (2·3 % for 6–23 months and 5·4 % for 24–59 months) was lower than that reported in the previous surveys. This finding needs to be carefully examined; however, geographic factors (such as latitude), outdoor activities and customary clothing may explain this difference.

Living at higher latitudes (northern or southern, depending on the hemisphere) is one of the main predictors of vitamin D insufficiency in population studies[21]. UVB radiation is more intense at lower latitudes, which favours the conversion of 7-dehydrocholesterol into vitamin D in the skin[1], thus decreasing the risk of vitamin D insufficiency. In the ENANI-2019, the prevalence was lower in regions with lower latitudes, such as the North (1·2 %) and Northeast (0·9 %) regions. Higher altitude areas (with colder climates) have also been identified as strong predictors of vitamin D insufficiency[7]. They should be considered even in tropical settings expected to receive UVB radiation year-round. However, given Brazil's geographical relief characteristics, this is not a relevant issue to be considered in studies conducted in this country. Moreover, we also observed a higher prevalence of vitamin D insufficiency among children living in urban areas than those living in rural areas, which may be explained by more outdoor activities in rural areas and, thus, more exposure to sunlight.

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Table 3. Association between vitamin D insufficiency and socio-demographic and health variables in Brazilian children aged 6–59 months, ENANI-2019

	Crude model			Adjusted model*		
Variables	Estimate (OR)	*P* value	95 % CI	Estimate (OR)	*P* value	95 % CI
Child age (months)						
6–23	(ref)			(ref)		
24–59	2·41	<0·001	1·55, 3·74	2·23	<0·001	1·52, 3·27
Child sex						
Female	0·97	0·81	0·72, 1·29	–	–	–
Male	(ref)			(ref)		
Brazilian geographical region						
North	1·38	0·59	0·42, 4·51	0·51	0·31	0·14, 1·85
Northeast	(ref)			(ref)		
Southeast	8·54	<0·001	3·39, 21·52	5·55	<0·001	2·34, 13·16
South	9·75	<0·001	4·03, 23·56	4·57	<0·001	1·77, 11·83
Midwest	2·57	0·04	1·05, 6·30	1·21	0·69	0·47, 3·14
Household location						
Urban	2·52	0·15	0·71, 8·91	1·62	0·41	0·52, 5·08
Rural	(ref)			(ref)		
National Wealth Score (Tertiles)						
1°	0·57	0·10	0·29, 1·11	1·52	0·21	0·79, 2·92
2°	1·21	0·49	0·70, 2·11	2·14	0·01	1·17, 3·91
3°	(ref)			(ref)		
Educational level of the mother/caregiver (completed years)						
0–7	0·54	<0·001	0·34, 0·85	0·53	0·05	0·28, 1·00
8–10	0·91	0·66	0·61, 1·37	0·85	0·55	0·51, 1·43
≥11	(ref)			(ref)		
Skin colour/race of child						
White	(ref)			(ref)		
Brown	0·43	<0·001	0·29, 0·63	0·61	0·04	0·38, 0·98
Black	0·34	<0·001	0·16, 0·74	0·44	0·03	0·21, 0·93
Excess weight (BMI Z > +2)						
No	(ref)			(ref)		
Yes	1·21	0·53	0·67, 2·18	–	–	–
Vitamin D supplement use						
Yes	(ref)			(ref)		
No	1·88	0·12	0·85, 4·15	1·71	0·17	0·79, 3·71
Season of blood collection						
Summer (December–February)	(ref)			(ref)		
Autumn (March–May)	2·52	0·04	1·05, 6·05	1·24	0·65	0·50, 3·05
Winter (June–August)	8·81	<0·001	3·93, 19·79	5·82	<0·001	2·66, 12·72
Spring (September–November)	8·09	<0·001	3·18, 20·63	4·84	<0·001	2·17, 10·80

Z BMI, body mass index Z-score.
* Adjusted by variables with *P* value < 0·20 in the crude model: child age, Brazilian geographical region, household location, National Wealth Score, educational level of the mother/caregiver, skin colour/race of child, vitamin D supplement use and season of blood collection.

The prevalence of vitamin D insufficiency is potentially higher among those with darker skin, given the higher concentration of melanin and, therefore, lower penetration of UVB through the skin[1]. Nevertheless, a pattern of higher prevalence of vitamin D insufficiency in those with higher skin pigmentation has not always been found[23,24]. In the present study, black and brown children had a lower prevalence of vitamin D insufficiency than white children. One hypothesis that may help explain this unexpected result refers to a higher proportion of white children in those Brazilian regions with lower insolation throughout the year (i.e. South and Southeast). Furthermore, while evaluating the influence of socio-economic factors, we observed a direct association between higher serum 25(OH)D concentrations and lower maternal education. This result can be partially explained by the fact that children whose mothers have lower education levels have worse socio-economic conditions, live less frequently in apartments, and have less access to electronic devices. Thus, they can engage in more outdoor activities, leading to the highest UVB radiation exposure, which may improve vitamin D synthesis.

National surveys in other countries have already reported a higher prevalence of vitamin D insufficiency in children aged > 2 years compared with those younger aged 1–2 years[8,25,26]. In ENANI-2019, we also observed a twofold increase in the risk of vitamin D insufficiency in children aged 24–59 months. In theory, the higher prevalence of vitamin D supplement use observed among children aged 6–23 months (34·5 %) compared with those aged 24–59 months (15·1 %)[27] might have contributed to the lower prevalence of insufficiency in the younger group. The higher supplement use observed among younger children is consistent with the Brazilian Society of Pediatrics recommendation for early use (children aged 0–24 months) of vitamin D supplements[28]. However, considering all children studied at ENANI-2019, the use of supplements did not reflect a decreased risk of vitamin D insufficiency, despite the slightly higher (~6 nmol/l) vitamin D serum concentrations observed in the supplement users. Furthermore, children whose blood was collected in the summer had 12·32 nmol/l higher serum 25(OH)D concentration than those whose blood was collected in the winter, reinforcing the importance of sun

Table 4. Association between serum 25(OH)D concentrations and socio-demographic and health variables in Brazilian children aged 6–59 months, ENANI-2019

	Crude model			Adjusted model*		
Variables	Estimate (β)	P value	95 % CI	Estimate (β)	P value	95 % CI
Child age (months)						
6–23	(ref)			(ref)		
24–59	−20·00	<0·001	−23·57, −16·43	−18·78	<0·001	−22·35, −15·20
Child sex						
Female	−5·57	<0·001	−7·94, −3·2	−5·66	<0·001	−7·81, −3·51
Male	(ref)			(ref)		
Brazilian geographical region						
North	−6·18	0·11	−13·78, 1·43	1·76	0·65	−5·80, 9·31
Northeast	(ref)			(ref)		
Southeast	−25·61	<0·001	−32·23, −18·99	−21·86	<0·001	−27·76, −15·96
South	−30·89	<0·001	−35·89, −25·89	−25·97	<0·001	−30·87, −21·08
Midwest	−17·59	<0·001	−23·32, −11·86	−12·27	<0·001	−17·33, −7·22
Household location						
Urban	−19·44	<0·001	−28·76, −10·13	−14·19	<0·001	−20·69, −7·68
Rural	(ref)			(ref)		
National Wealth Score (tertiles)						
1°	7·30	<0·001	2·79, 11·82	−1·29	0·55	−5·57, 2·99
2°	3·73	0·05	0·01, 7·47	−1·69	0·34	−5·14, 1·76
3°	(ref)			(ref)		
Educational level of the mother/caregiver (completed years)						
0–7	6·34	<0·001	2·85, 9·84	4·33	0·01	0·96, 7·69
8–10	4·30	0·06	−0·26, 8·85	2·71	0·15	−0·96, 6·38
≥11	(ref)			(ref)		
Skin colour/race of child						
White	(ref)			(ref)		
Brown	8·72	<0·001	5·82, 11·61	2·15	0·08	−0·25, 4·56
Black	6·51	0·06	−0·15, 13·17	2·12	0·38	−2·63, 6·87
Excess weight (BMI Z > +2)						
No	(ref)			(ref)		
Yes	0·32	0·92	−6·14, 6·78	–	–	–
Vitamin D supplement use						
Yes	(ref)			(ref)		
No	−9·81	<0·001	−14·73, −4·89	−6·01	<0·001	−9·64, −2·39
Season of blood collection						
Summer (December–February)	(ref)			(ref)		
Autumn (March–May)	−12·81	<0·001	−20·88, −4·74	−0·46	0·88	−6·50, 5·57
Winter (June–August)	−21·46	<0·001	−28·18, −14·73	−12·31	<0·001	−18·95, −5·68
Spring (September–November)	−21·02	<0·001	−28·51, −13·53	−11·88	<0·001	−18·62, −5·15

Z BMI, body mass index Z-score.
* Adjusted by variables with P value < 0·20 in the crude model: child age, child sex, Brazilian geographical region, household location, National Wealth Score, educational level of the mother/caregiver, skin colour/race of the child, vitamin D supplement use and season of blood collection.

exposure as the primary source of vitamin D. Lower serum 25(OH)D concentrations in girls are consistent with previous findings[22].

In Brazil, there are no public policies regulating food fortification with vitamin D or vitamin D supplementation. A study conducted with school-age children from several Latin American countries (Guatemala, El Salvador, the Dominican Republic, Honduras, Nicaragua, Costa Rica, Panama, Belize and Mexico) with no vitamin D supplementation policies for children also revealed very low (3·6 %) prevalence of vitamin D insufficiency (< 50 nmol/l)[29], a result aligned with what we found for ENANI-2019. Vitamin D supplement use was not explored in the few Brazilian population studies on vitamin D status. Nationally representative data on vitamin D status in Brazil are restricted to adults ≥ 50 years[30], showing a prevalence of vitamin D insufficiency of 16 %. Additionally, a multicentric study (twenty-seven state capitals of municipalities with > 100 000 inhabitants from each of the country's five macroregions) conducted with Brazilian adolescents observed that vitamin D insufficiency was prevalent in 21 % of the participants[31].

The ENANI-2019 revealed a lower prevalence of vitamin D insufficiency compared with other studies in Brazilian children, in which the prevalence of vitamin D insufficiency (< 50 nmol/l) ranged from 13·6 % to 68·2 %[9,10]. In a local study accomplished in a city in the Brazilian Amazon region, the prevalence of vitamin D insufficiency was 14·6 % in children < 25 months and 13·6 % in children aged 25 to < 60 months[9]. In another study conducted with children aged 11–15 months in primary health units in four Brazilian cities, the prevalence of vitamin D insufficiency was 68·2 %[10]. Besides the sample size and representativeness of the ENANI-2019 sample, which may better reflect the vitamin D status of children < 5 years, the use of different laboratory methods may have contributed to the differences in the results between studies. This highlights the importance of participating in international quality assurance programs. Despite the lack of national data, the Brazilian Society of Pediatrics recommends early vitamin D supplementation to children, following international guidelines[28]. The findings from ENANI-2019 provide evidence for reviewing this recommendation.

The present study had some limitations. Among the eligible children (aged 6–59 months), 70 % had their blood drawn; therefore, basic sample weights and calibration adjustments were used. Calibration helps prevent differential nonresponse effects that can affect sample-derived estimates. Serum 25(OH)D concentrations were not measured using the high-performance liquid chromatography/mass spectrometry gold standard method. To overcome this and certify the quality of our results, the performance of the chemiluminescence immunoassay used to analyse vitamin D was verified using DEQAS. Data that would help to better understand the determinants of cutaneous synthesis of vitamin D, such as time spent outdoors and the use of sunscreen, were not collected. In addition, because of the low prevalence of vitamin D insufficiency, some estimates showed a CV > 30 % and may not be accurate. Nevertheless, our study has several strengths, especially because it is a nationally representative survey with a large sample size. Moreover, this is the first national survey to explore the vitamin D status in Brazilian children.

In conclusion, in this nationally representative survey in a country with a high incidence of UVB and middle income, we observed a low prevalence of vitamin D insufficiency in children aged 6–59 months, which should not be considered a public health problem.

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