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Socioeconomic and environmental determinants and hypovitaminosis D in adolescents in the northeast of Brazil: a hierarchical approach

Determinantes socioeconômicos e ambientais e hipovitaminose D em adolescentes no nordeste do Brasil: uma abordagem hierarquizada

Determinantes socioeconómicos y ambientales e hipovitaminosis D en adolescentes del noreste de Brasil: un enfoque jerárquico

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Abstract
Family socioeconomic and environmental conditions are associated with health status and disease outcomes in infancy, acting at different levels of determination over these events, positively or negatively affecting individuals. Methods was adopted a hierarchical approach to investigate a vitamin D insufficiency and socioecomimc determinants in the basic, intermediate, and immediate levels. The logistic regression and odds ratio (OR) as an association measure were used to assess the relationship of interest. The prevalence of vitamin D insufficiency (10-29.9 ng/ml) was 54.1% of the adolescents, no vitamin D deficiency (<10 ng/ml) was identified. At the basic level, was observed a 52% protective effect (OR = 0.48; p< 0.003) of the low socioeconomic stratum for the occurrence of insufficient vitamin D levels; living in rural area increased by 2.35 times more chances of having insufficient vitamin D levels (OR = 2.35; p < 0.001). At the intermediate level, the sanitary conditions of the household situated at the lowest level of the distribution tercile, resulted in a 1.41% higher risk (OR = 2.41; p < 0.034) of those conditions being associated with vitamin D insufficiency. At the immediate level, the results showed that those with 14-years had 2.37 times more chances (OR = 2.37; p < 0.024) and to be black/brown skin (OR = 2.00; p < 0.047) were associated with vitamin D insufficiency. Conclusion socioeconomics factors and individual level were associated with vitamin D insufficiency in adolescents.
Keywords: Hypovitaminosis D; Socioeconomic factors; Hierarchical approach; Adolescents; Brazil.

Resumo
As condições sociais, econômicas e do ambiente familiar se associam aos desfechos do estado de saúde e da doença na infância, atuando em diferentes níveis da determinação destes eventos, afetando positiva ou negativamente os indivíduos. Métodos adotou-se a abordagem hierárquica para examinar a insuficiência de vitamina D e determinantes socioeconômicos nos níveis básico, intermediário e imediatos. Regressão logística e a medida de associação *odds Ratio* (OR) foram usadas para avaliar a relação de interesse. Prevalência de insuficiência de vitamina D (10-29,9 ng/ml) foi registrada em 54,1 % dos adolescentes, não ocorreu a deficiência de vitamina D (<10 ng/ml). No nível básico observou-se o efeito protetor de 52% (OR=0,48; p< 0,003) do estrato social e econômico baixo para e a ocorrência de níveis insuficientes de vitamina D viver na área rural aumentou 2,35 vezes mais chances de terem níveis insuficientes de

vitamina D (OR=2,35 p< 0,001). No nível intermediário, as condições sanitárias do ambiente domiciliar situadas no nível mais baixo do tercil de distribuição, resultaram em risco mais elevado de 1,41% (OR=2,41; p=0,034) se associaram com a insuficiência de vitamina D, no nível imediato os resultados mostraram que aqueles com 14 anos de idade tiveram 2,37 vezes mais chances (OR=2,37; p<0,024) e ter a cor da pele parda + preta (OR= 2,00; p<0,047) se associaram com a insuficiência de vitamina D. Conclusão :Fatores socioeconômicos e nível individual se associaram com a insuficiência de vitamina D em adolescentes.
Palavras-chave: Hipovitaminose D; Fatores socioeconômicos; Abordagem hierárquica; Adolescentes, Brasil.

Resumen
Las condiciones sociales, económicas y del entorno familiar están asociadas con los resultados de salud y enfermedad en la infancia actuando en diferentes niveles en la determinación de estos eventos, afectando positiva o negativamente a los individuos. Métodos se adoptó un enfoque jerárquico para examinar la insuficiencia de vitamina D y los determinantes socioeconómicos en los niveles básico, intermedio e inmediato. Se utilizaron la regresión logística y la medida de asociación o la razón de possibilidades (OR) para evaluar la relación de interés. Se registró prevalencia de insuficiencia de vitamina D (10-29,9 ng/ml) en el 54,1% de los adolescentes, no hubo deficiencia de vitamina D (<10 ng/ml). En el nivel básico se observó un efecto protector del 52% (OR=0.48; p< 0.003) del estrato social y económico bajo, y la ocurrencia de niveles insuficientes de vitamina D que habitan en zonas rurales aumentó 2.35 veces más las posibilidades de tener niveles insuficientes de vitamina D (OR=2,35 p< 0,001). En el nivel intermedio, las condiciones sanitarias del ambiente domiciliario, ubicado en el nivel más bajo del tercil de distribución, resultó en un mayor riesgo de 1,41% (OR=2,41; p=0,034) asociado a insuficiencia de vitamina D, en el nivel inmediato , los resultados mostraron que los mayores de 14 años tenían 2,37 veces más probabilidades (OR=2,37; p<0,024) de tener color de piel marrón + negro (OR= 2,00; p<0,047) y se asociaron con insuficiencia de vitamina D. conclusión Factores socioeconómicos y el nivel individual se asociaron con insuficiencia de vitamina D en adolescentes.
Palabras clave: Hipovitaminosis D; Factores socioeconomicos; Abordagem jerárquica; Adolescente; Brasil.

1. Introduction

Vitamin D is a group of fat soluble secosteroids, primarily responsible for increasing intestinal absorption of calcium, magnesium, and phosphorus. The main sources of vitamin D in human are the exposure in sun light, from dietary and vitamin D supplementation (Holick, 2007). Vitamin D deficiency in children is associate with some skeletal diseases as rickets, however, among adolescents low levels of vitamin D is correlated with cardiometabolic risk factors (Reis et al, 2009). Chronic diseases encompass a range of morbidities and together with deficiency diseases they form a panorama of major epidemiological importance in the modern world. Among deficiency diseases, hypovitaminosis D is one of the most prevalent, affecting the population in general (Holick, 2017; Santos Araujo et al., 2017; Pereira-Santos et al., 2018), with a high occurrence also among adolescents (Hintzper et al., 2008; Neves et al., 2019; Delvin, 2010). Given the epidemiological importance of deficiency diseases in the population, there has been a search to understand their determinants. Based on the historical knowledge regarding disease development, socioeconomic factors are recognized as lying at the origin of their determination (Fang et al., 2010), especially in the case of deficiency diseases. It is also understood that unfavorable socioeconomic relationships are expressed in inequalities in the access to and use of health services, substantially raising the morbidity burden, negatively affecting more socially vulnerable individuals and/or groups (Morcillo et al., 2019). In that sense, nutritional deficiencies, especially hypovitaminosis D, are historically associated with unfavorable socioeconomic determinants. In those conditions, these determinants can also influence the individual's behavior and lifestyle and be associated with the population's survival and wellbeing. However, there is still no consensus on the occurrence of these determinants and their role in determining diseases (Melamed et al., 2008; Wakayo et al., 2015, Paes-Silva et al., 2018). One of the reasons highlighted for the absence of a consensus by various investigators concerns the definition of socioeconomic determinants in health adopted among epidemiological studies and their impacts on morbimortality conditions in populations. In the search to understand the influence of the determinants of health status and nutrition, these determinants are addressed in various ways by various fields of knowledge.

Independently of the theoretical-methodological discussion on the topic, the low socioeconomic conditions of families have been one of the main predictors of hypovitaminosis D in adolescents (Hintzper et al., 2008; Al-Agha et al., 2016) and possibly for other deficiency morbidities as well. The epidemiological studies that cover these relationships using the concepts of wealth or poverty generally adopt isolated variable such as family income, parental and/or maternal educational level, or type or quality of housing (Victora et al., 1997), among other predictors, ignoring the hierarchy between the levels of determination of the diseases. Thus, to differentiate the influence of the determinants of deficiency diseases, the United Nations International Children´s Emergency Fund (UNICEF) proposed the hierarchical model of determination of protein-energy malnutrition and other deficiency diseases.

The hierarchical model is an explanatory approach elaborated by UNICEF (1990) to relate the factors of the social structure, the household environment, and the individual that interact to determine health and nutrition conditions (UNICEF, 1998). This approach may be a strategy that better explains the relationship between these events, possibly as it favors the definition of a methodologically consistent theoretical model and a statistical model that considers the complexity and interconnection between the determinants of the association investigated. At the basic level of determination lie the variables or indicators related to families' socioeconomic conditions, which are interconnected with the intermediate ones represented by the conditions of the sanitary environment of the household and its surroundings, for example the water source, the existence and type of toilet, the sewage system, and waste disposal (Assis et al., 2007; Victora et al., 1997), which directly or indirectly influence the proximal or immediate determinants that are related to the individual. The multilevel models are very important to use because it has more advantages when compared to traditional linear regression, since the multilevel approach can be used to modelling more complex analysis in unbalanced data and unequally space of data collection. It can estimate within and between person effects and this model is not limited only to regression analysis. Other advantage of this method is to incorporate multiple level of information, which gives more plausibility and accuracy (Witte et al, 2000). This study aimed to identify the hypovitaminosis D in adolescents, and socioeconomic determinants according to different levels of the hierarchical model.

2. Methodology

2.1 Study design and location

This was a cross-sectional study design, using data from the second wave of the quantitative survey AMACOMP ("Breastfeeding and complementary weaning diet – nutritional and health status in the first two years of life – a cohort study") cohort implemented in the municipalities of Laje and Mutuípe, originally involving children born at the maternity units in the period from 2005 to 2006 (first wave) and revisited (second wave) in 2019 at 11 to 14 years of follow-up. The municipalities of Laje and Mutuípe are located in the Recôncavo Sul area of the state of Bahía in Brazil, with estimated populations of 23,840 and 22,221 inhabitants, respectively (IBGE, 2019). The second wave research project obtained approval from the Human Research Ethics Committee of the School of Nutrition of the Federal University of Bahia (UFBA) via decision n. 3,561,321.

2.2 Sample

The sample of this study involves 342 adolescents participating in the AMACOMP cohort, identified and examined among 525 participants from the first wave (Fonseca, 2012) with biological material available and adequately stored in an ultra-freezer at -70°C in 2019. In the original sample, 183 participants (34.8%) were lost in the 11 to 14 years of follow-up. Of the 358 participants of the study identified in the second wave, it was not possible to collect or there was a loss of the blood sample of 16 (4.46%), leaving a final sample of 342 (95.5%) adolescents. For the sample of 342 adolescents in this study, we estimate in 99.9% power considering 5% error, and two-tailed tests to evaluate the relationship investigated, based on a 51.5% prevalence of hypovitaminosis D in adolescents in the city of São Paulo (Petres et al., 2012).

2.2.1 Data collection

The blood collection for the vitamin D dosage was carried out at Family Health Units with the agreement of the Health Department. in the rural and urban areas of the municipalities. The blood was collected from 9 September to 30 November, 2019. The participants of the study were directed by the team of investigators regarding preparation to carry out the exams, particularly regarding fasting for 12 hours beforehand. A total of 10 mL of blood was collected by venipuncture using a vacuum tube with separator gel and BD-type disposable needles. The collection was carried out by suitably trained nursing technicians and the blood processing and conditioning were performed at the laboratory of one of the municipalities. After the collection, the blood was centrifuged for 15 minutes at 2000 rpm to separate the serum. The serum samples were identified by codes for the cohort members and stored in a freezer at that laboratory. They were then transported to the laboratory of the School of Nutrition of the Federal University of Bahia (UFBA). Subsequently, they were sent to the Laboratory of the Association of Parents and Friends of Exceptional Individuals (Apae) in Salvador, where the biochemical analysis of hydroxyvitamin D [25(OH)D] was carried out.

2.3 Preparation of the variables and data analysis

Information on the socioeconomic, demographic, and household sanitary environmental conditions were provided by the adolescent or their guardian and recorded in a structured questionnaire. The adolescent's weight and height were calculated in duplicate, accepting a maximum variation of 100g for weight and 0.1cm for height. When higher values occurred, a third measure was taken and the mean between the closest values of the two measurements was adopted as the final measure (Lohman et al., 1998).

The weight measure was carried out using a Welmy® microelectronic balance, model W200M, with 150kg capacity and 50g precision. Height was calculated using a Slim Fit portable stadiometer. The adolescents were weighed wearing light clothing, barefooted, and free of accessories, belts, and objects in their clothes pockets.

The crude body mass index (BMI and age) was adopted to assess the adolescent's anthropometric status. It was obtained by dividing weight (kilograms) by height (meters) squared [BMI = W(kg)/H(m^2)] (De ONIS et al., 2007) for the 5 to 19 age group and classified in percentiles: obese ≥P95th, overweight <P85th-P95th, eutrophic ≥P5th-85th, and thin <P5th (CDC, 2002). Excluded stratified variables here because

The vitamin D [25(OH)D] dosage was carried out using the chemiluminescence immunoassay (CLIA) method (DIASORIN & Lialson, 2019). The logistic regression with a hierarchical approach was used in the data analysis and the odds ratio (OR) was the association measure (Hosmer & Lemeshow, 2000; Wickenstd, 1998). A p-value <0.05 was adopted to accept the associations investigated in the final multivariate model.

In this study, the outcome variable is represented by the serum concentration of vitamin D. In the absence of a universal definition for characterizing vitamin D levels (Santos Araújo et al., 2017; Rosen, 2011; Munns et al., 2016) in adolescents, we chose to adopt the one of the Brazilian Society of Clinical Pathology and Laboratorial Medicine (2017), which is most common in clinical practice in Brazil. Thus, the vitamin D concentration was categorized in three levels: sufficiency (30-100 ng/ml = 0), insufficiency (10-29.9 ng/ml = 1), and deficiency (<10 ng/ml = 2). This study did not identify a deficient level of vitamin D.

The exposure variables were separated into two or more categories. Those with more than two levels were converted into their respective dummies (Hosmer & Lemeshow, 2000) and are presented in a self-explanatory table in the results section. The exposure variables are represented by the socioeconomic conditions of the family (basic or distal level), the sanitary environment and the household structure (intermediate level), and aspects relating to the adolescent (proximal or immediate level), thus allocating the hierarchical levels as recommended by UNICEF (1990) for the hierarchical approach to determining protein-energy malnutrition and other deficiency diseases.

The variables of the basic or distal level of the hierarchy, which involve the families' socioeconomic conditions, were structured in the criteria of the Brazilian Association of Population Studies (ABEP, 2019) and are represented by the ABEP index. This index is formed of the sum of the 10 items (bathroom, automobile, maid and having a washing machine, videocassette and/or DVD, independent fridge and freezer or as part of a duplex device, microwave, microcomputer, washing machine and dryer).

To that index, the ABEP adds the educational level of the head of the family (defined as: illiterate/incomplete elementary, illiterate/up to the 3rd elementary series (0); complete elementary/incomplete junior high up to the 4th elementary series (1); complete junior high/incomplete high complete elementary (2); complete high school/incomplete college complete middle school (worth 4 and complete college 8 points). This index also includes the conditions related to public services: running water and paving at the household location. The sum of these points classifies the families into eight classes, as follows: A1 (42-46); A2 (35-41); B1 (29-34); B2 (23-28); C1 (18-22); C2 (14-17); D (8-13); and E (0-7).

We chose to include isolated socioeconomic variables in this level that are theoretically related to the health conditions of the population and not included in this index, represented by the urban (0) or rural (1) area of residence; occupation of the head of the family, categorized as housewife + entrepreneur + retired + self-employed (0), rural worker (1), or unemployed + handyman (2); and the sex of the head of the household: male (0) or female (1). This designation was similar to the monthly income among them and/or working relationship, but when the frequency informed was low, we chose to combine them, even if that premise was broken. When indicated, the variable was categorized in its respective dummies.

The intermediate level of the hierarchical approach is made up of the sanitary conditions of the household and public services available within the household and its surroundings. To assess the relationship between these variables and the adolescent's vitamin D level, we adopted the environmental index based on the proposal of Issler and Giugliani (1997), adapted by Oliveira et al. (2007) and already tested and validated in previous studies of the Center of Nutrition and Epidemiology School of Nutrition- Federal University of Bahia (ENUFBA). It is built based on 10 variables of the original index: existence of sewage near the household (no = 0 or yes = 1); destination of domestic waste (public collection = 0 or burnt and thrown into an open area = 1); destination of domestic waste (public collection = 0 or thrown into an open area, stream, or river = 1); toilet conditions (individual with a flush = 0 or none, not individual, or no flush = 1); water source (public = 0 or well, stream, or river = 1). Three of these variables were excluded from the index as they were common to the ABEP index.

These indicators are interpreted based on the sum of weighted points, which vary from 0 (unfavorable conditions) to 4 (more favorable conditions), totaling 0 to 28 points, characterizing the environmental conditions of the household and surroundings. This score was subsequently distributed in terciles, forming a growing risk based on the most favorable conditions to the least favorable ones. It is recognized that these conditions normally reflect the influence of the socioeconomic conditions that form the basic level.

For the analysis of the proximal level, which reflects the influence of the basic and intermediate level variables, theoretically associated with the adolescent's vitamin D concentration, the following variables were included in the statistical model: skin color (white + indigenous + yellow = 0 or black + brown = 1); age (11 to 13 years old = 0 or 14 years old = 1); sex (male = 0 or female = 1); BMI and age in percentile (CDC, 2002); use of sunscreen (yes = 0 or no = 1). The binary variables were categorized as 0 (when protective) and 1 (represents the risk condition). The variables categorized into three or more levels were transformed into dummies, always expressing the risk in increasing order. Thus, level 0 represents the protection of the variable in the event and an increase in that level indicates the risk of the event studied increasing. When necessary, the levels of the variables were collapsed based on the epidemiological or clinical coherence and in special situations based on the distribution of the occurrence of the event in the population.

After these preliminary statistical steps were completed, we analyzed the frequency of the distribution of the selected variables and the bivariate logistic regression, with the aim of describing the sample and choosing the candidate variables for the multivariate model. In this stage, we chose all the variables whose associations indicated a p-value ≤ 0.20; but for the analysis of the third level we included other variables whose p-values were higher, but for which the literature showed epidemiological importance for the event. Subsequently, we proceeded with the multivariate logistic regression analysis, starting with the basic level variables. All the variables allocated to this level that presented a p-value <0.05 were chosen to compose this hierarchical block and formed part of the analysis models of the subsequent blocks.

As a second analysis step, we included in the multivariate model the previously chosen variables as candidates for the intermediate block which, adjusted by the basic level variables, provided the definitive range of intermediate level variables (p <0.05). Finally, we carried out the third and final step of the multivariate statistical analysis, including all the basic and intermediate level variables already chosen for the final model, to adjust this analysis level, adding the previously chosen variables for the proximal level. All the associations with p-values <0.05 composed the proximal level. Thus, the final model was built.

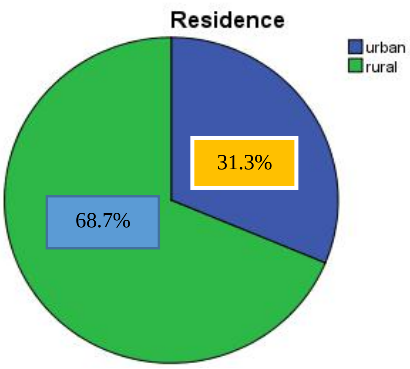
3. Results

The baseline information indicates that most 68.7% of the participants of the study lived in the rural area (Figure 1); 52.3% had rural workers as heads of their families and 13.0% of the heads of family were unemployed or handymen at the time of the interview and 63.5% were illiterate or had an educational level characterized as incomplete elementary. It was observed that 70.8% of the adolescents belonged to a family classified as low socioeconomic class, according to the ABEP criterion (Figure 2). An expressive portion lived in residences with semi-adequate 44.7% and inadequate 30.4% environmental conditions, respectively (Table 1).

The characterization of the immediate level variables the anthropometric status evaluated by the BMI and age (percentile) indicated that 75.7% of the adolescents were eutrophic; 12.9% and 6.9% were overweight and obese, respectively, and only 4.5% were thin (Figure 3), and 52.9% of the participants were male; 46.0% self-declared as brown and 37.5% as black (Figure 4) and 85.2% were 14 years old. Most did not use sunscreen 85.0% and normally 63.1% walked from home to school or did so to the bus stop, when they lived in the rural area.

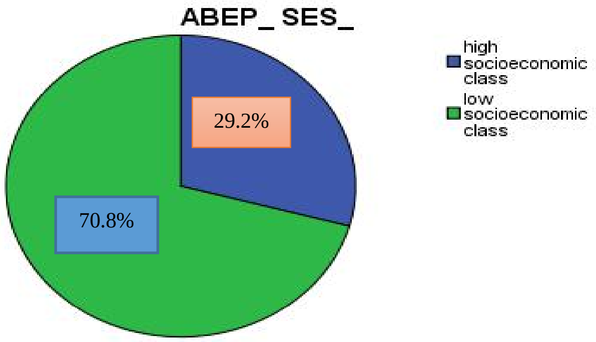
The concentration of vitamin D (ng/ml) in the sample had a mean distribution of 30.17 ng/ml (SD = 9.0); sufficient vitamin D levels (30-100 ng/ml) were observed in 45.9% of the adolescents and insufficient levels (10-29.9 ng/ml) in 54.1%. No cases of deficiency (<10 ng/ml) were recorded (Table 1).

Figure1. Area of residence.



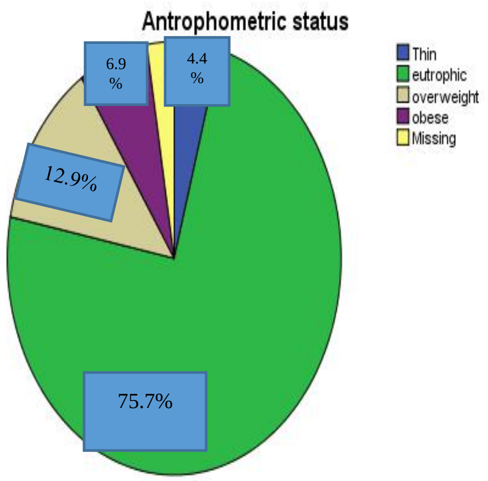
Source: Authors.

Figure 2. socioeconomic status.



Source: Authors.

Figure 3. Anthropometric status.



Source: Authors.

Figure 4. skin color.

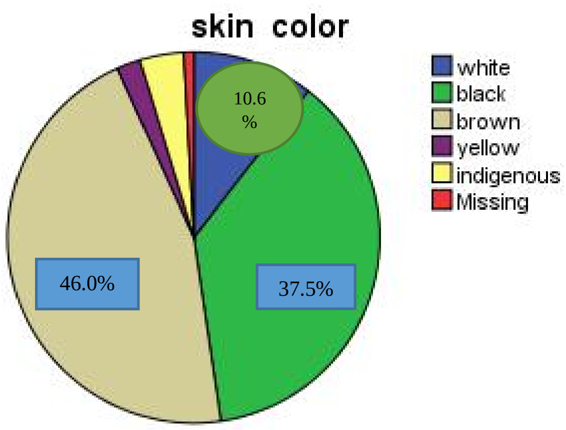


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Table 1. Adolescent and family characterization of participants of the second wave of the Amacomp Cohort, Laje and Mutuípe, 2019.

VARIABLES	N	%
Basic Hierarchical Level Variables		
Family socioeconomic class – ABEP	**342**	
High socioeconomic class (A- C2) (0)	100	29.2
Low socioeconomic class (D+E) (1)	242	70.8
Area of residence	**342**	
Urban area (0)	107	31.3
Rural area (1)	235	68.7
Distribution of basic level variables (ABEP)		
The family has a computer	**342**	
Yes (0)	61	17.8
No (1)	281	82.2
The family has a microwave oven	**342**	
Yes (0)	73	21.3
No (1)	269	78.7
The family has a dishwasher	**342**	
Yes (0)	23	6.7
No (1)	319	93.3
There is a toilet in the house	**342**	
Yes (0)	306	89.5
No (1)	36	10.5
The family has an automobile	**342**	
Yes (0)	88	25.7
No (1)	254	74.3
There is a maid in the house	**342**	
Yes (0)	27	7.9
No (1)	315	92.1
There is a washing machine	**342**	
Yes (0)	229	37.7
No (1)	213	62.3
There is a video cassette or DVD	**342**	
Yes (0)	156	45.6
No (1)	186	55.4
There is a fridge	**342**	
Yes (0)	321	93.9
No (1)	21	6.1
There is a motorcycle	**334**	
Yes (0)	99	29.6
No (1)	235	70.4
There is a dryer	**342**	
Yes (0)	57	16.7
No (1)	285	83.3
Paving conditions at the house	**342**	
Paved (0)	131	38.3
Dirt track (1)	211	61.7
Availability of running water at the house	**342**	
Yes (0)	134	39.2
No (1)	208	60.8
Education of the head of the family	**342**	
Complete college + complete high school (0)	61	17.8
Complete elementary 2 + incomplete high school (1)	64	18.7

Illiterate + incomplete elementary 1 (2)	217	63.5
Occupation of the head of the family	**331**	
Housewife + entrepreneur + retired + self-employed (0)	115	34.7
Rural worker (1)	173	52.3
Unemployed + handyman (2)	43	13.0
Intermediate hierarchical level variables	**N**	**%**
Modified environmental index (in points) - MOD_ENV	**342**	
Adequate (≥ 25) (0)	85	24.9
Semi-adequate (20 to 24) (1)	153	44.7
Inadequate (0 to 19) (2)	104	30.4
Distribution of the intermediate level variables (MOD_ENV)		
Household ownership condition	**342**	
Own (0)	305	89.2
Rented (1)	23	6.7
Sub-rented (2)	14	4.1
Type of household illumination	**342**	
Public (0)	303	89.4
Others (solar energy, generator, lamp) (1)	36	10.6
Number of residents in the household	**338**	
1 to 4 residents (0)	212	62.7
5 to 10 residents (1)	128	37.3
Number of rooms in the house	**342**	
6 to 11 (0)	117	34.4
4 to 5 (1)	188	55.3
0 to 3 (2)	35	10.3
Number of inhabitants per household	**342**	
≤ 2 (0)	262	76.6
>2 (1)	80	23.4
Regular trash collection in the street of the household	**341**	
Yes (0)	123	36.1
No (1)	218	63.9
Variables added to the intermediate level		
Sex of the head of the family	**273**	
Male (0)	211	77.3
Female (1)	62	22.7
Immediate level variables	**N**	**%**
Sex of the participant of the study	**342**	
Male (0)	181	52.9
Female (1)	161	47.1
Race or skin color (self-reported)	**339**	
White + yellow + indigenous (0)	56	16.5
Brown (1)	156	46.0
Black (2)	127	37.5
Age of the participant (in years)	**359**	
11 to 13 (0)	53	14.8
14 (1)	306	85.2
Age of the mother (in years)	**342**	
28 to 45	129	37.7
46 to 57	213	62.3
Anthropometric status (in percentiles)	**333**	
Thin <$P5^{th}$	15	4.5
Eutrophic $P5^{th}$-$P85^{th}$	253	75.7

Overweight ≥P85th-P95th	43	12.9
Obese ≥P95th	23	6.9
Sunscreen use	**334**	
No (0)	284	85.0
Yes (1)	50	15.0
Walks from home to school	**290**	
Yes (0)	183	63.1
No (1)	107	36.9
Season of the year when the blood was collected	**340**	
Spring (0)	224	65.9
Winter (1)	116	34.1
Distribution of vitamin D serum levels	**342**	
Sufficient (30-100 ng/ml)	157	45.9
Insufficient (10-29.9 ng/ml)	185	54.1
Mean vitamin D concentration (SD)[ng/ml]	30.17	SD = 9

ABEP- Brazilian Association of Population Studies

Table 2 presents the crude and adjusted OR values and their respective confidence intervals and p-values. We chose to include these two statistical significance parameters to provide more elements for evaluating the epidemiological and statistical importance of the event. The adjusted multivariate model indicated that living in the rural area of the municipalities gave the adolescent a higher risk (OR = 2.35; CI95% = 1.41-3.92; $p < 0.001$) of having vitamin D insufficiency, compared with those who lived in the urban area. The low socioeconomic class gave the adolescent 52% protection (OR = 0.48; CI95% = 0.28-0.82; $p < 0.003$) in terms of having sufficient vitamin D levels when compared to with those from the higher socioeconomic class. The sanitary conditions of the household environment and surroundings, included in the intermediate level of the hierarchy, when adjusted by the basic level conditions, resulted in a higher risk, located in the third tercile of the distribution (OR = 2.41, CI95% = 1.06-5.44; $p < 0.034$), associated with insufficient vitamin D levels among the adolescents, when compared with that of the best tercile of the distribution of that indicator.

Among the proximal level variables, after adjusting for the basic level and intermediate level variables of the hierarchy, it was identified that a higher age increases the chance (OR = 2.37; IC95% = 0.25-0.86; $p < 0.024$) of having insufficient vitamin D serum levels when compared with the highest age. Having a mother aged from 35 to 57 years old had a 55% protective effect (OR = 0.45; IC95% = 0.25-0.86; $p < 0.001$) in terms of the adolescent having insufficient vitamin D levels, when compared with the vitamin D levels of those whose mothers were between 28 and 34 years old. Having black or brown skin gave the adolescent a greater (OR = 2.00; IC95% = 1.00-3.97; $p < 0.047$) chance of having insufficient vitamin D levels when compared with the whites, indigenous, and yellow adolescents (Table 2).

Table 2. Crude and adjusted odds ratio for the association between the socioeconomic determinants and hypovitaminosis D in adolescents, Laje e Mutuípe, 2019**.**

Variable	Crude OR	CI 95%	P value	Adjusted OR	CI 95%	P value
Basic level						
Area of residency						
Urban	1			1		
Rural	2.35	1.41-3.92	0.01	2.35	1.41-3.92	0.00
Socioeconomic classes - ABEP						
High socioeconomic classes	1			1		
Low socioeconomic classes	0.66	0.41-1.06	0.08	0.48	0.28-0.82	0.00
1. First analysis level adjusted with the area of residence and family socioeconomic class variables. Omnibus test of the coefficient model: χ2 = 13.919, sig = 0.001.						
Intermediate level						
Conditions of the household environment and surroundings						
Sex of the head of the household						
Male	1	-	-	-	-	-
Female	0.900	0.11-1.58	0.715			
Modified environmental index	1			1		
2nd tercile (semi-adequate) (Dummy-1)	1.50	0.88-2.56	0.13	1.93	0.93-4.01	0.07
3rd tercile (inadequate) (Dummy-2)	0.57	0.99-3.17	0.05	2.41	1.06-5.44	0.03
2. Second analysis level adjusted for the first and second level variables: modified environmental index in terciles, mother's age, and sex of the head of the household, Omnibus test of the model: χ2 =13.278, sig=0.021						
Immediate level						
*Sex of the adolescent						
Male	1	-	-	-	-	-
Female	1.40	0.12-1.40	0.12			
Age of the adolescent (years)						
11 to 13	1					
14	1.75	0.96-3.186	0.06	2.37	1.10-5.02	0.02
Mother's age (years)						
28 to 34	1					
35 to 57	0.66	0.42-1.02	0.06	0.45	0.25-0.86	0.00
Race or skin color (self-reported)	1					
White + indigenous + yellow						
Brown + black	1.73	0.97-3.09	0.06	2.00	1.00-3.97	0.04
Anthropometric status						
Overweight + obese	1					
Eutrophic + thin	0.89	0.56-1.65	0.96			

3. Third level: adjusted by the first and second level variables and the adolescent's age, the adolescent's sex, skin color, and anthropometric status variables. Omnibus test of the model: χ2 = 31.329, sig = 0.000*. Source: Authors.

4. Discussion

A high prevalence of hypovitaminosis D in adolescents is observed in various parts of the world, varying from 40.7% in Thais (Reesukmal et al., 2015) to 86.0% in adolescents in Paraná, a region with a cold climate located in southern Brazil (Robl et al., 2016). A high prevalence of insufficient vitamin D levels (21-29 ng/ml) (42.7%) was also identified in healthy adolescents from sunny areas in northeastern Brazil, residing in João Pessoa (Santos-Araujo et al., 2017).

Similar results were reported in India by Puri et al. (2008) and in Ethiopia by Wakayo et al (2015) for vitamin D and social conditions. However, results incompatible with the findings of this study were reported in Indian adolescents (Marwaha et al., 2005) and in the city of Recife, where there was no indication of any difference for serum concentrations of vitamin D and socioeconomic conditions (Linhares et al., 1984).

In the Southeast region, in Juiz de Fora (Minas Gerais), insufficiency (10-30 ng/ml) was observed in 70.6% of those in this phase of life (Oliveira et al., 2013). Meanwhile, in São Paulo, also in the Southeast region, the prevalence of vitamin D insufficiency (21-29 ng/ml) in 51.5% among the adolescents (Petres et al., 2012). Although there is no information on vitamin D deficiency at a population-wide level in Brazil, particularly among adolescents, and the available data do not enable us to trace the epidemiological panorama of this deficiency, these prevalence rates together with those identified in the present study surely indicate that the occurrence of hypovitaminosis D is expressive among Brazilian adolescents.

Given the epidemiological importance of this deficiency, studies conducted at a global level seek to identify the influence of the factors associated with the occurrence of hypovitaminosis D, highlighting the economic, environmental, sociocultural, and behavioral determinants. Thus, there is a well-known historical theory that adequate socioeconomic conditions are positively associated with the health and nutritional status of populations, reducing the occurrence of various diseases, especially deficiency ones, including hypovitaminosis D, resulting in the assertion that individuals from high socioeconomic levels have higher vitamin D concentrations. But strangely the opposite is also recorded by the results of some studies that have identified that inadequate socioeconomic life conditions are protective in terms of maintaining adequate serum levels of some nutrients, especially vitamin D, a relationship observed in various regions of the world (Hintzper et al., 2008; Al-Agha et al., 2016).

The results of this study developed in municipalities in the state of Bahia in Brazil add to those that associate the protective role of low socioeconomic conditions in maintaining some health and nutritional conditions of populations. The highlight for discussing these results converges toward the two opposite fields of knowledge. The first is promoted by the historical thinking on disease determination where a lack of basic means of subsistence leads to health inequality, limiting the access to and use of instruments available in society and health care services, increasing the risk of diseases, including hypovitaminosis D (Al-Agha et al., 2016).

The second aspect of that result is based on the explanatory pillar of the origin of diseases, particularly the mechanism that seeks to sustain the theory of the protective effect of the relationship between low socioeconomic class and the attenuation of risk to health, including vitamin D deficiency. It is understood that the plausibility for this result is explained by the greater likelihood of adolescents who live in socioeconomic inequality engaging in physical activity outdoors, increasing walking time for daily activities, increasing the opportunity for sunlight exposure, with limited access to the use of sunscreen, as well as consuming whole-fat foods, an important source of vitamin D. These considerations are explained in results of studies recorded by Kim (2019) in South Korea, Salamoun et al. (2005) in Lebanon, and Kapil et al. (2017) in India for hypovitaminosis and the socioeconomic conditions of adolescents.

However, these results should be viewed with caution and are not applicable to all protective conditions that can result from inadequate socioeconomic conditions and health situations. This is particularly so because there is a historically recognized dampening role of inadequate socioeconomic conditions in the health and nutritional status of populations, recorded in the distant past and also nowadays in various studies (Santoge et al., 2009; Gu et al., 2019; Morcillo et al., 2019). This is especially true when the structural bases of the causes of nutritional deficiencies are historically associated with socioeconomic determinants and health inequalities (Gu et al., 2019).

In this sense, the unfavorable relationships negatively affect less socially advantaged individuals or groups (Morcillo et al., 2019) and are expressed in inequalities in the access to and use of health services, reflecting not only in the field of deficiency diseases, but in most of the morbidities that affect the population.

In addition, most of the epidemiological studies that investigate the relationship between morbidities and socioeconomic conditions traditionally adopt isolated predictors (Victora et al., 1997) of the events studied. These basic or distal level variables, represented by socioeconomic conditions, are interconnected with the intermediate level variables, represented by the sanitary conditions of the household and surroundings (Oliveira et al., 2006; Assis et al., 2007; Daniel et al., 2019), which directly or indirectly affect the predictive strength of the immediate or proximal variables related to the individual (UNICEF, 1998).

Possibly, the inconsistency observed between the results of these studies and the majority line on the determination of health can also be explained by various methodologies adopted in different fields of knowledge to assess the socioeconomic conditions of the population. This is particularly true due to the lack of a consensus on the parameters or indicators that best define and identify the determinants of families' socioeconomic conditions and their impacts on morbimortality conditions in populations (Melamed et al., 2008; Wakayo et al., 2015, Paes-Silva et al., 2018).

Seeking to understand the results that indicate the protective effect of inadequate socioeconomic conditions over the adequacy of serum vitamin D levels in the adolescents in this study, it can be commented that the socioeconomic conditions were evaluated using the ABEP indicators and it was observed that the low socioeconomic class gave 52% protection (OR = 0.48; CI95% = 0.28-0.82; p <0.003) in terms of the adolescents having sufficient vitamin D levels.

This indicator is routinely used in studies in the field of health in Brazil, with good reproducibility and sensitivity for evaluating this aspect. However, we cannot fail to consider that most of the population of this study was viewed as being of a low socioeconomic class (D+ E) (70.8%) using the ABEP methodology, which may have led to an indicator that did not discriminate the socioeconomic strata of this population well or even the absence of some variable not included in the methodological/statistical model that could alter the direction of the association.

However, it is appropriate to consider that most of the families of this study reside in the rural area (68.7%) and that living in the rural area leads to a 2.35 times higher chance (OR = 2.35; CI95% = 1.41-3.92; p <0.00) of the adolescent having vitamin D insufficiency. Only 29.2% of the families had a socioeconomic condition characterized as high (Table 1). However, put this way, these data do not enable us to conclude that living in a rural area plays a role in affecting the risk of occurrence of hypovitaminosis D in the families of this study. We also cannot ignore at this point the chance that the conditions of the household environment and surroundings, at the intermediate level associated with the proximal level variables, lead to a high occurrence of hypovitaminosis for the adolescents in this study, given the close relationship between the indicators at these hierarchical levels. Assis et al. (2007) observed in children of municipalities in northeastern Brazil whose families were located in the poorest economic tercile, lived in the rural area, and whose paternal unemployment was high, that as the child moved from the richest tercile to the poorest one, the inadequacies of the environmental and health conditions increased. Similar results were also recorded by Oliveira et al. (2006) in studies involving children in municipalities in northeastern Brazil. There was also no investigation in this cohort of the effect of the family's participation in social programs, which would contribute to understanding the determination of vitamin D levels and the lowest socioeconomic conditions, besides the possible adoption of a survival mechanism to overcome inadequate living conditions. Unfortunately, the relationship was not investigated in depth in this study.

In this study, the intermediate level variables adjusted by the basic level conditions resulted in a higher risk, located in the third tercile of the distribution (OR = 2.41; CI95% = 1.06-5.44; p <0.034). The results of this study add to the pre-existing evidence that black or brown skin could discriminate the individual's social class and may be associated with the risk factor for the event (Clemens et al., 1982; Ohlund et al., 2013). Meanwhile, a younger child and older mother/guardian of the child act as protective factors against the occurrence of diseases in infancy (Daniel et al., 2019; Oliveira, 2007) and in the adequacy of vitamin D levels (Morisset et al., 2016).

In addition, in societies where socioeconomic and health inequality is high and there are social welfare programs established for example *Auxílio Brasi*l in Brazil to minimize inequality and overcome poverty in the family unit, these are mostly granted to women, (Martns & Monteiro, 2016). We can also highlight the benefit of rural pensions, where it is common for the woman to be a beneficiary of that program, possibly reflecting in a protective effect of the mother's age group (35 to 57 years old) and, thus, older women's' participation in maintaining the family income, indirectly and positively reflecting in the family income and in the child's serum concentration of vitamin D.

5. Conclusion

In this study was found that the socioeconomic factors located in basic, intermediate and individual level were associated with vitamin D insufficiency in the participants. Curiously, in the basic level of determination, those from low socioeconomic class were protect to being a vitamin D insufficiency, similar results were found by other epidemiology studies from other countries for example in India and Ethiopia. It may be explained by using a theory that support among those adolescents from low socioeconomic status, they are always exposed to sun light, walking by foot, many activities in outdoors, these daily routine increase a vitamin D production and avoid a vitamin D insufficiency or deficiency when compared with other from high socioeconomic status. We also, recommend in the future carried out more studies with sample compound by adolescents and investigate strictly this relationship socioeconomic factors and vitamin D status to generate more robust evidences about this apparently controversy. In this study these results are consistent taking into account that more than half of this sample lived in rural areas and they were from low socioeconomic status, according to the criteria used in this study to classified the socioeconomic status.

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