CSP CADERNOS DE SAÚDE PÚBLICA
REPORTS IN PUBLIC HEALTH

ARTIGO
ARTICLE

Individual and contextual predictors of children's hemoglobin levels from Southern Brazilian municipalities in social vulnerability

Preditores individuais e contextuais dos níveis de hemoglobina em crianças de municípios do Sul do Brasil com vulnerabilidade social

Predictores individuales y contextuales de los niveles de hemoglobina en niños socialmente vulnerables de municipios del Sur de Brasil

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doi: 10.1590/0102-311X00166619

Abstract

Few studies have investigated the simultaneous effect of individual and contextual factors on the occurrences of anemia. This study aims to evaluate the variability of children's hemoglobin levels from municipalities in social vulnerability and its association with factors of individual and municipal nature. This is a cross-sectional, multi-center study, with children data (12-59 months) collected from 48 municipalities of the Southern region of Brazil, that were included in the Brazil Without Poverty Plan. Individuals' data were collected using a structured questionnaire, and secondary and ecological data of children's municipalities were collected via national surveys and institutional websites. The outcome was defined as the hemoglobin level obtained by HemoCue. A multilevel analysis was performed using Generalized Linear Models for Location Scale and Shape using R, with a 5% significance level. A total of 1,501 children were evaluated. The mean hemoglobin level was 12.8g/dL (95%CI: 12.7-12.8), with significant variability between municipalities. Lower values of hemoglobin were observed in children who lived in municipalities with a higher urbanization rate and a lower number of Community Health Agents, in relation to the reference categories. At the individual level, lower hemoglobin values were identified for children under 24 months, not enrolled at daycares, who were beneficiaries of the conditional cash transfer program and diagnosed with underweight. The results shed light on important factors at the municipal and the individual levels that were associated to the hemoglobin levels of children living in municipalities in social vulnerability.

Hemoglobin; Anemia; Child; Multilevel Analysis

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Introduction

Low blood levels of hemoglobin characterize anemia, a common deficiency in children under five years of age, with biological, social, and economic implications. According to estimates from the World Health Organization, 273 million children around the world presented low levels of hemoglobin in 2011, with variable distribution among the continents; with numbers up to 12.7 million children in Europe, 17.1 million in the Americas, and 96.7 million in Southeast Asia [1].

Despite the methodological differences observed in the studies, anemia is usually considered a moderate problem of public health in children under five years of age in Brazil [1,2]. Based on hemoglobin levels, the occurrence of anemia is frequent in this age group, and it can be a severe condition in population groups living on areas of socio-economic vulnerability [3,4,5,6,7]. Therefore, changes in life conditions and reduction of social inequalities have been prioritized in Brazil by policy makers, especially for infant's first years of life [8,9,10].

The implementation of social programs and policies in Brazil since the 1990s has contributed to the increase of the population's income and their access to public goods and services [11,12]. However, evidence shows that the impact of these programs and policies on children's health and nutrition was not homogeneous throughout the country, even within these regions [13]. To reduce these inequalities, the *Brasil Sem Miséria* (Brazil Without Poverty) Plan was launched in 2011, not only to try to remove millions of Brazilians from poverty, but also to reduce the manifestations and aggravation of this condition [14]. The government designed this Plan to help the less informed, most fragile and most isolated population, which is usually the group least assisted by public policies, and that often only has access to low-quality services [15]. Among the main strategies of this Plan, there was the *Brasil Carinhoso* (Brazil that Cares) action, which prioritized strategies related to early childhood, involving the prevention of iron deficiency in this group [16].

Although iron deficiency due to dietary intake is recognized as the main cause of low hemoglobin levels [1,17], there is a growing interest in the influence of living conditions on the development of this deficiency in children [18]. Previous studies [19,20,21,22,23,24,25] have emphasized the impact of poor living conditions on the prevalence of anemia and hemoglobin levels. Nevertheless, few have investigated the simultaneous effect of individual and community factors on the occurrence of anemia [26]. Thus, this research intended to evaluate the variability of children's hemoglobin levels from the Southern municipalities included in the Brazil Without Poverty Plan and their association with factors at the municipal and individual levels.

Methods

This was a cross-sectional multi-center study on the prevalence of hypovitaminosis A and anemia in children (12-59 months) residing in municipalities from the Southern region of Brazil, comprising the states of Paraná, Santa Catarina and Rio Grande do Sul. This region has one of the highest urbanization rates, level of education, and average monthly income in Brazil [27]. It also holds the smaller coefficients of infant mortality and illiteracy [27]. Despite these good indicators, in 2014, 2.4% of the population from this region lived in poverty with a monthly income per capita less than BRL 140.00 (approximately USD 42.04) and 0.7% in extreme poverty, earning less than BRL 70.00 (approximately USD 21.02) [28].

As for the sample size, the estimation was done considering the set of municipalities that were exclusively members of the Brazil Without Poverty Plan in 2012 that were not covered by the National Vitamin A Supplementation Program in 2014. This set was adopted because the determination of hypovitaminosis A was also a goal of the multi-center study. In each of the three Southern states, the primary sampling unit (PSU) was considered to be the municipalities. The calculation of the sample size considered a 21.5% prevalence of anemia in children less than five years old in Southern Brazil, maximum error of 5%, 95% confidence interval (95%CI), infinite population, and sampling and design effect (deff) of 1.5. Furthermore, the design effect was reduced by the adoption of at least one-third of the eligible municipalities in each PSU. Therefore, it was defined by the selection of 16 municipalities, totaling 48 municipalities in the region. As a result, the sample size was estimated at 389 children per state, followed by the inclusion of 25% to cover possible losses, totaling 500 children, approximately 32 per municipality.

Children between 12 and 59 months old who were present in the basic health units (UBS) during the data collection days were selected to participate in the study. Exclusion criteria were children who performed blood transfusions and its derivatives; who were under immunosuppressive or cortico-therapeutic therapy; who had chronic illnesses; who were HIV-infected or had any severe infectious condition; who had congenital malformation and/or who were hospitalized due to diarrhea in less than a month.

Data collection was conducted by trained dieticians and took place from January to June 2015. It consisted of a face-to-face interview with the mother or legal guardian to apply a structured questionnaire in the UBS of each municipality. Then, blood samples from the children were collected and their weight and height, measured.

The questionnaire included individuals' demographic, socioeconomic, and environmental information. The blood was collected by peripheral venipuncture and a drop of the collected blood was placed on a flat surface (glass slide). Then, the tip of a microcuvette touched the sample drop to capture the necessary amount of blood, followed by the immediate reading of the hemoglobin levels in a portable hemoglobinometer (HemoCue, HemoCue Limited, Sheffield, U.K.). The test was performed in duplicate for hemoglobin values less than 11g/dL [17], adopting the mean values. The weight and height data were collected in duplicate, following standardized procedures [29]. The indexes height-for-age (HAZ), weight-for-age (WAZ), and body mass index-for-age (BMI) were then classified according to the cut-off points of the z-score [30].

The children's hemoglobin level (g/dL) was the dependent variable in this study. The selected independent variables were defined based on a theoretical model that considered reference studies in the area. These variables were classified in two levels: individual, which covers the children's variables; and municipal, which contains variables related to the municipalities.

The children's variables with significant association in a previous bivariate analysis ($p < 0.05$) were included in this study: (1) children's age (< 24 months or ≥ 24 months); (2) maternal/legal guardian's race/color (white or non-white: black, brown, yellow, indigenous or other); (3) monthly household income per capita based on minimum wage (MW) in 2015 (BRL 788.00/USD 236.63) (no income or income up to ¼ of the MW, income between ¼ and ½ MW, income between ½ and 1 MW or income higher than 1 MW); (4) number of residents in the house (up to 3, 4 to 5, 6 or more); (5) mother/legal guardian's occupation (unemployed, employed with/without social security number or other (housewife, student or retired); (6) number of times the child went to the UBS in the year preceding the research (0 to 5 times, 6 to 12 times or more than 12 times); (7) enrollment at daycare center or kindergarten (yes or no); (8) Beneficiary of the *Bolsa Família* Program (Brazilian Income Transfer Program) (yes or no); (9) nutritional status according to the WAZ index (underweight – for both underweight and severely underweight children –, normal weight or overweight); (10) use of ferrous sulfate (never been taken, yes it was taken or yes still take it) and (11) beneficiary of the Paraná food fortification program called *Leite das Crianças* (Milk for Children) (yes, no or not applicable).

At the municipal level the variables were obtained or calculated using secondary and ecological data, available in national surveys and institutional websites, namely: (1) municipal Human Development Index in 2010 [31]; (2) Gini coefficient in 2010 (http://www.tabnet.datasus.gov.br/cgi/ibge/censo/cnv/ginibr.def.html); (3) monthly nominal income in 2015 (BRL. https://cidades.ibge.gov.br/); (4) extremely poor population in 2010 (%) [31]; (5) urbanization rate in 2010 (%) [31]; (6) adequate sanitation in 2010 (%) [31]; (7) coverage of basic health care in 2014 (%. https://www.egestorab.saude.gov.br/paginas/acessopublico/relatorios/relHistoricoCoberturaAB); (8) Standardized number of community health agents (ACS) deployed in 2014, calculated as the number of agents considered when financial incentives were received from the Brazilian Ministry of Health in 2014 divided by the population of these localities in the same year (https://www.egestorab.saude.gov.br/paginas/acessopublico/relatorios/relHistoricoCoberturaAB); (9) attendance at daycare centers in 2010 (%) [32]; and (10) infant mortality rate in 2014 [33]. All variables selected to compose the municipal level were categorized according to their quartiles, so that higher quartiles correspond to favorable life conditions or to better availability of public goods and services, except for the Gini coefficient and the percentage of the extremely poor population. Additionally, the infant mortality rate was not categorized by quartiles. It was considered low when less than 5/1,000 live births, moderate when between 6-15/1,000 and high when more than 16/1,000 live births.

The characteristics of the children and the municipalities were described by absolute and relative frequencies and by measures of central tendency and dispersion. The multilevel analysis was based on the methodology of Generalized Additive Models for Location Scale and Shape (GAMLSS) [34], considering the non-normal distribution of hemoglobin levels.

Among the available models for continuous random variables, without the inclusion of independent variables, we verified the model with the best adjustment of hemoglobin levels according to the Akaike information criterion (AIC). For this criterion, the lower the value produced by a model, the greater its ability to explain the data adequately with a smaller quantity of parameters [35]. Based on this result, the probabilistic model chosen was the Johnson's SU-distribution, defined by four parameters: mean (μ); standard deviation (σ); and two shape parameters (τ and ν) [36]. Since it is a four parameters model, Johnson's SU-distribution allows modeling data with different levels of skewness and kurtosis. In the present study, the blood hemoglobin levels presented a fat-tailed distribution (high kurtosis), which was not properly fitted by the normal or other models based on fewer parameters. Although we have selected a four parameters model, the covariates were used only to model the location parameter, μ. Some additional attempts were performed to assess the inclusion of covariates for the remaining parameters, but we did not verify any substantial improvement in the fitted model. Finally, the identity link function was applied for the location parameter, such that the covariate effects on the mean hemoglobin levels must be interpreted additively.

Afterwards, we selected the variables for the adjusted model following two steps: (1) considering the variables at the municipal level; and (2) considering the variables at the individual level, including those selected at the first step. These variables were only included in the modeling of the mean distribution, an important parameter for measuring hemoglobin level of the individuals. As for the variability between the hemoglobin levels of children from different municipalities, a random variable with normal distribution of mean zero and variance was incorporated in the analyses.

The association between the municipal variables and the hemoglobin level was initially evaluated without adjusting the effect of the remaining municipal variables and verified by the likelihood-ratio test. The variables with $p < 0.20$ were selected for the sequence of the analysis, with adjustment to the effect of the remaining variables at this level. After this adjustment, the variables considered to be significant were those with $p < 0.05$. Then, the variables at the individual level were added one by one to the model adjusted by the municipal variables. Those that produced $p < 0.20$ in the test of likelihood-ratio were the ones which remained for the sequence of the analysis. Finally, we proceeded with a new selection in the model adjusted with all variables selected in both steps, based on the backward strategy. In this step, the variables with a smaller contribution to the adjustment, according AIC values, were removed from the adjusted model one by one. The identification of the final model occurred when the removal of any variable of the model would produce a higher AIC value. To calculate the mean hemoglobin level for each category of the variables that remained in the final model, the effect of the remaining variables was fixed to the mean.

Data were double-entered and validated on EpiData, version 3.2 (http://www.epidata.dk/) and evaluated statistically in the software R, version 3.4.2 (http://www.r-project.org) at the significance level of 5%. The package GAMLSS was applied in the choice of the probabilistic model and in the regression analysis.

The multi-center study was approved by the Ethics Committee in Research with Human Beings of the Federal University of Health Sciences of Porto Alegre (Protocol n. 722.702/2014) and all children's mothers or legal guardians signed an informed consent form.

Results

A total of 1,567 children were evaluated in the multi-center study. The dosage of hemoglobin levels was possible in 1,501 of them, which resulted in a sample loss of 4.2%. The characteristics of the children can be found in Table 1 and the characteristics of the municipalities in Table 2.

Table 1

Characteristics (n and %) of the children (12-59 months) sample, Brazil Without Poverty Plan. Southern Region, Brazil, 2015 (N = 1,501).

Children variables	n	%
Monthly household income per capita based on minimum wage (MW *) [n = 1,383] **		
≤ 1/4	382	27.6
> 1/4 and ≤ 1/2	339	24.5
> 1/2 and ≤ 1	392	28.3
> 1	270	19.5
Type of water consumed by children [n = 1,446]		
Filtered, boiled, tap or mineral	1,030	71.2
Other types (well, mine or others)	416	28.8
Number of residents in the house [n = 1,434] **		
Up to 3	513	35.8
4 to 5	732	51.0
6 or more	189	13.2
Maternal/legal guardian's age (years) [n = 1,450]		
< 20	108	7.5
20 to 35	1,027	70.8
> 35	315	21.7
Maternal/legal guardian's race/color [n = 1,430] **		
White	874	61.1
Non-white	556	38.9
Parity of biological mother [n = 1,455]		
Primiparous	585	40.2
Multiparous	870	59.8
Mother/legal guardian's occupation [n = 1,467] **		
Unemployed	73	5.0
Housekeeper with or without formal employment relationship	763	52.0
Others (housewife, student, retired)	631	43.0
Health unit model [n = 1,501]		
Traditional	175	11.7
Family Health Strategy	1,326	88.3
Follow-up in the UBS since birth [n = 1,460]		
No	101	6.9
Yes	1,259	93.1
Received home visit in the previous year [n = 1,446]		
No	158	10.9
Yes	1,288	89.1
Number of times the child went to the UBSt in the year preceding the research [n = 1,121] **		
0 to 5	676	60.3
6 to 12	243	21.7
> 12	202	18.0

(continues)

Table 1 (continued)

Children variables	n	%
Enrollment at daycare centers or kindergarten [n = 1,477] **		
No	770	52.1
Yes	707	47.9
Beneficiary of the Brazilian Income Transfer Program [n = 1,458] **		
No	794	54.5
Yes	664	45.5
Child's age (months) [n = 1,501] **		
< 24	389	25.9
≥ 24	1,112	74.1
Child's gender [n = 1,501]		
Male	775	51.6
Female	726	48.4
Height for age index (Z-score) [n = 1,409]		
Stunted/Severely stunted (< -2)	90	6.4
Normal height (≥ -2)	1,319	93.6
Body mass for age index (Z-score) [n = 1,391]		
Wasted/Severely wasted (< -2)	32	2.3
Eutrophic (≥ -2 and ≤ +1)	923	66.4
Risk of becoming overweight (> +1 and ≤ +2)	307	22.1
Overweight and obese (> +2)	129	9.3
Weight for age index (Z-score) [n = 1,420] **		
Underweight (< -2)	25	1.8
Normal weight (≥ -2 and ≤ +2)	1,296	91.3
Overweight (> +2)	99	7.0
Beneficiary of the Paraná food fortification Program Milk for Children [n = 1,500] **		
No	336	22.4
Yes	198	13.2
Not applicable	966	64.4
Age of enrollment in the Program Milk for Children (months) [n = 196]		
< 12	181	92.4
12 to 23	10	5.1
24 to 36	5	2.5
Use of ferrous sulfate [n = 1.386] **		
Never been taken	683	49.3
Yes, it was taken	645	46.5
Yes, I still take it	58	4.2

MW: minimum wage; UBS: basic health unit.

* MW: BRL 788.00/USD 236.63;

** Children's individual variables selected for multilevel analysis.

Table 2

Characteristics of the municipalities, Brazil Without Poverty Plan. Southern Region, Brazil, 2015 (n = 48).

Municipal characteristics	Median	Minimum	Maximum
Municipal Human Development Index (2010)	0.67	0.59	0.97
Gini coefficient (2010)	0.50	0.37	0.70
Monthly nominal income (2015) (BRL)	2.00	1.60	4.20
Extremely poor population (2010) (%)	8.40	0.82	28.95
Urbanization rate (2010) (%)	39.28	9.35	97.40
Adequate sanitation rate (2010) (%)	10.45	0.60	84.60
Coverage of basic health care (2014) (%)	100.00	45.69	100.00
Number of deployed Community Health Agents (2014) *	0.002	0.001	0.003
Attendance at daycare centers (2010) (%)	29.97	8.17	62.41
Infant mortality rate (per 1,000 live births) (2014)	4.80	0.00	39.46

* The number of deployed Community Health Agents was calculated as follows: the number of agents considered when financial incentives were received from the Brazilian Ministry of Health in 2014 divided by the population of these localities in the same year.

The mean hemoglobin level was 12.8g/dL (95%CI: 12.7-12.8g/dL). Figure 1 shows the variability of the hemoglobin levels among the municipalities, without and with the adjustment for the variables of the final model proposed. In both cases, a significant variability was observed in hemoglobin levels between the municipalities ($p < 0.001$), with a variance reduction of $\sigma^2_m = 0.25$ to $\sigma^2_m = 0.19$ in the adjusted model. Furthermore, the municipalities 3 and 14 stood out as they had the most negative effects on the average hemoglobin levels, while the municipalities 19 and 40 stood out for having the most positive effects.

As for the municipal variables included in the first model, the Municipal Human Development Index, monthly nominal income, adequate sanitation, urbanization rate, number of ACS and attendance at daycare centers remained at $p < 0.20$. After adjusting for other variables of this same level, only the nominal monthly income, urbanization rate, number of ACS and the attendance at daycare centers had a significant effect ($p < 0.05$) on the hemoglobin level, and, thus, remained in the model to adjust the variables of the individual level.

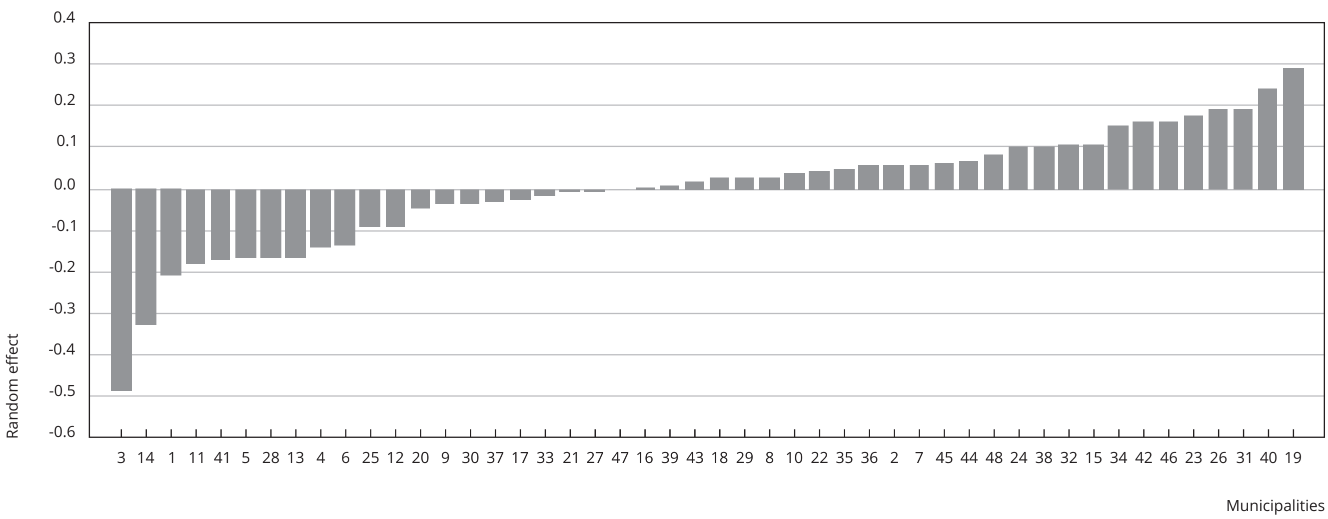
Subsequently, variables at the individual level that remained in the model were: children's age, maternal/legal guardian's race/color, monthly household income per capita, number of residents in the house, maternal/legal guardian's occupation, number of times the child went to the UBS in the year preceding the research, enrollment at daycare centers or kindergarten, beneficiary of the Brazilian Income Transfer Program, WAZ index and the use of ferrous sulfate. Finally, after adjustment of the model, the municipal factors that showed a significant effect ($p < 0.05$) on the mean hemoglobin level were urbanization rate and number of ACS; and the individual factors were children's age, enrollment at daycare centers, participation as a beneficiary of the Brazilian Income Transfer Program and WAZ index.

Table 3 shows only the estimates of the variables that remained in the final model while their effect in the children's mean hemoglobin level can be visualized in Figure 2. Children from municipalities with higher urbanization rates had lower mean hemoglobin levels when compared to children from municipalities with lower urbanization rates (quartile 1), that is 0.18 ($p = 0.016$) lower than children of quartile 2, and 0.16 lower than quartiles 3 ($p = 0.024$) and 4 ($p = 0.033$). Concerning the ACS, the positive effect of this variable was significant ($p = 0.003$) only in the children's hemoglobin levels of quartile 2, who presented a mean level 0.22 higher than those of quartile 1. Furthermore, children older than 24 months had a mean hemoglobin level 0.37 ($p < 0.001$) higher than younger children. Regarding the access to social protection policies, children who were beneficiaries of the Brazilian Income Transfer Program had a mean hemoglobin level 0.23 ($p < 0.001$) lower than those without

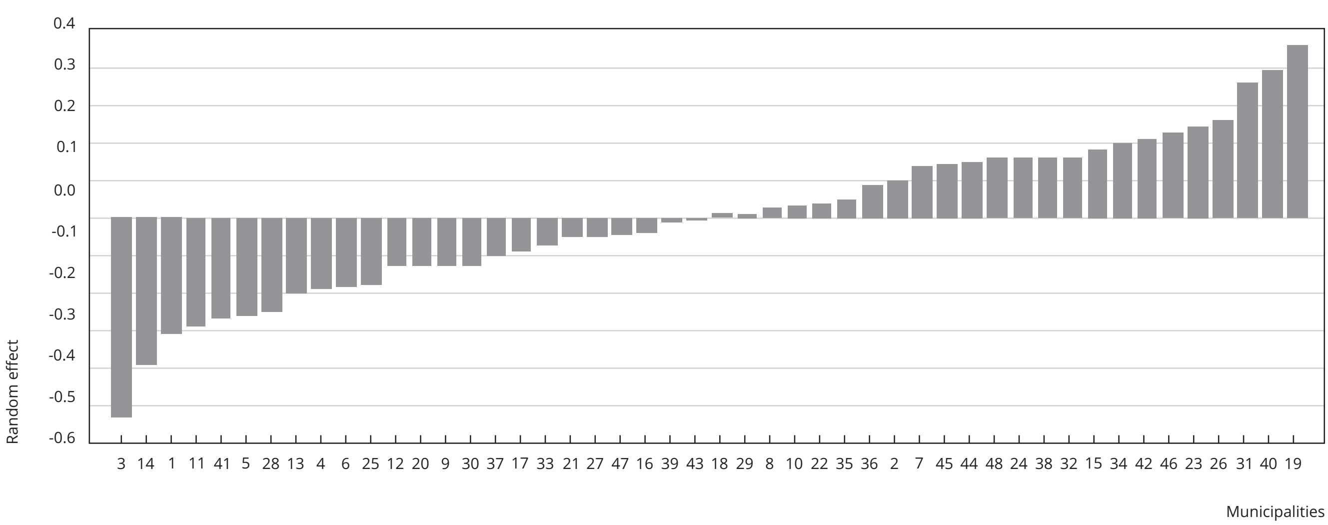
Figure 1

Estimates of the levels of hemoglobin in children (12 to 59 months) without and with adjustment by the variables of the multi-level model, according to the municipality included in the Brazil Without Poverty Plan, Southern Region, Brazil, 2015.

1a) Without adjustment



1b) With adjustment



the benefit. In contrast, children enrolled at daycare centers had a mean level 0.21 ($p = 0.001$) higher than those not enrolled in such institutions. As for nutritional status, children with normal weight or overweight had a mean hemoglobin level 0.60 ($p = 0.003$) and 0.74 ($p = 0.001$) higher than children with underweight, respectively. The other parameters of the model were estimated by $\sigma = 1.04$ and $\nu = -0.48$, revealing slight asymmetry of the data to the left, and by $\tau = 1.65$

Table 3

Individual and municipal variables related to the variability of hemoglobin levels of children (12-59 months), Brazil Without Poverty Plan. Southern Region, Brazil, 2015 (n = 1.501).

Individual and municipal variables	Without adjustment			With adjustment		
	Estimate	Standard error	p-value	Estimate	Standard error	p-value
Urbanization rate (quartile) [n = 48]						
Q1	Reference (1)			Reference (1)		
Q2	-0.21	0.07	0.005 *	-0.18	0.08	0.016 *
Q3	-0.19	0.07	0.006 *	-0.16	0.07	0.024 *
Q4	-0.16	0.07	0.037 *	-0.16	0.07	0.033 *
Number of ACS deployed [n = 48]						
Q1	Reference (1)			Reference (1)		
Q2	0.22	0.07	0.003 *	0.22	0.07	0.004 *
Q3	0.04	0.07	0.536	0.05	0.07	0.471
Q4	0.09	0.07	0.194	0.13	0.07	0.070
Child's age (months) [n = 1,501] **						
< 24	Reference (1)			Reference (1)		
≥ 24	0.40	0.06	< 0.001*	0.37	0.06	< 0.001*
Enrollment at daycare centers or kindergarten [n = 1,477] **						
No	Reference (1)			Reference (1)		
Yes	0.31	0.05	< 0.001 *	0.21	0.05	0.001 *
Beneficiary of Brazilian Income Transfer Program [n = 1,458] **						
No	Reference (1)			Reference (1)		
Yes	-0.22	0.05	< 0.001 *	-0.23	0.05	< 0.001 *
Weight for age index (Z-score) [n = 1,420] **						
Underweight (< -2)	Reference (1)			Reference (1)		
Normal (≥ -2 and ≤ +2)	0.70	0.20	0.001 *	0.60	0.20	0.003 *
Overweight (> +2)	0.84	0.22	< 0.001 *	0.74	0.22	0.001 *

ACS: community health agents.

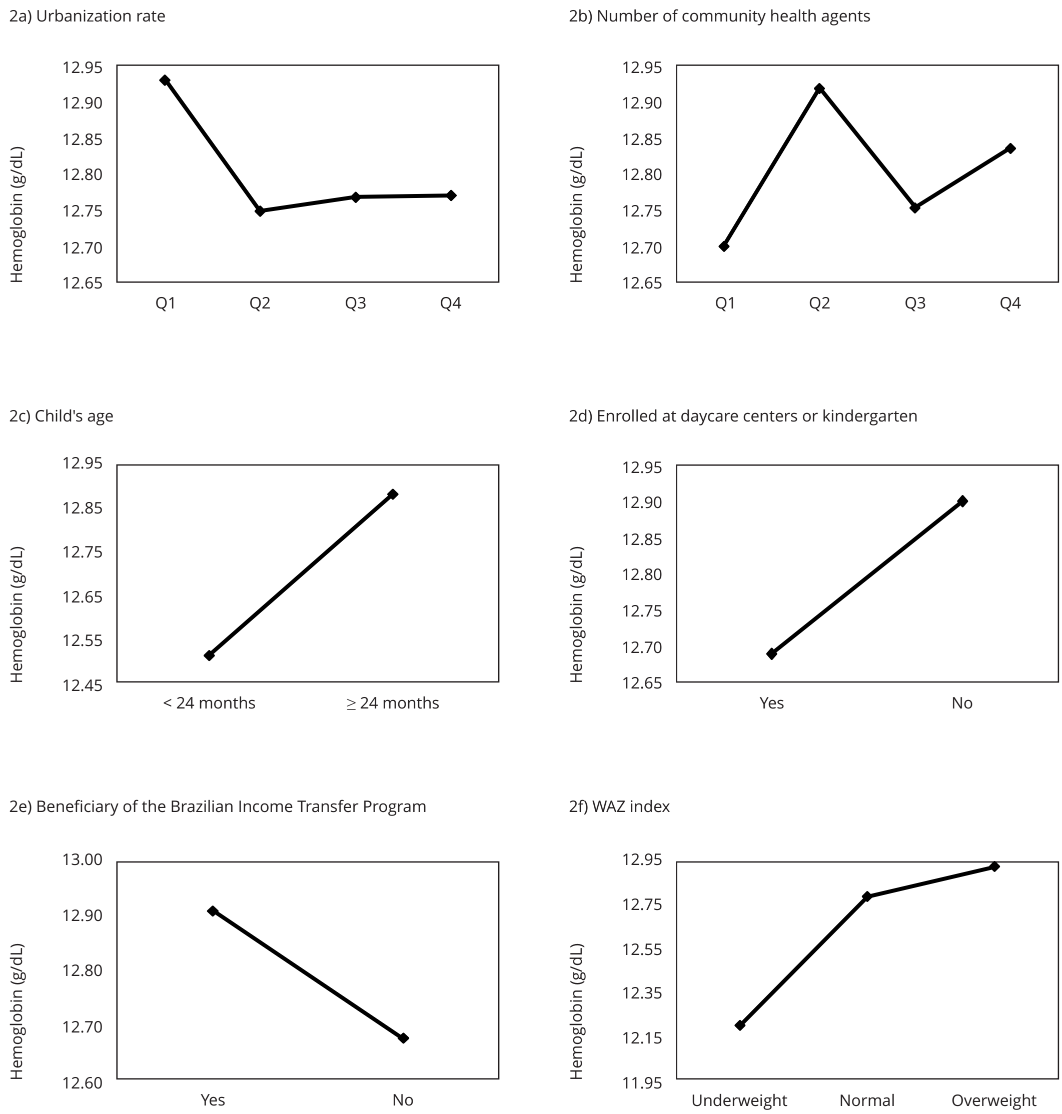
Notes: the number of ACS deployed was calculated by dividing the number of suitable agents for the municipality to receive financial incentives from the Brazilian Ministry of Health in 2014 by the population of these localities in the same year.

* Individual and municipal variables with significant effect (p < 0.05) on hemoglobin levels;

** Variables adjusted by municipal variables: monthly nominal income in 2015 (BRL), urbanization rate in 2010 (%), number of ACS deployed in 2014 and attendance at daycare centers in 2010 (%).

Figure 2

Estimates of hemoglobin levels (g/dL) of children (12-59 months), by individual and municipal variables, with a significant effect at $p < 0.05$, Brazil Without Poverty Plan, Southern Region, Brazil, 2015.



ACS: community health agents; Q: quartiles; WAZ: weight for age.
Note: the number of ACS was calculated by dividing the number of suitable agents for the municipality to receive financial incentives from the Brazilian Ministry of Health in 2014 by the population of these localities in the same year.

Discussion

The children's mean hemoglobin level in this study (12.8g/dL; 95%CI: 12.7-12.8g/dL) was higher than the internationally adopted cut-off points for the diagnosis of anemia in children (6-60 months). It was also higher than the international estimates (11.1g/dL; 95%CI: 11.0-11.3g/dL) [1] and the national representative values (12.1g/dL ± 1.5g/dL) for children (6-59 months) [2]. In addition, this value was higher than evidenced by other studies with children from different Brazilian epidemiological scenarios, which varied between 11.1g/dL and 12.5g/dL [22,37,38]. However, these comparisons should be interpreted with caution, due to the different methodologies used by other studies, especially when measuring the hemoglobin levels.

Even though the Southern region of Brazil has one of the best indicators of social, economic and educational development in the country [27], it is still marked by inequalities that influence the health and nutrition of the most vulnerable population. In fact, significant variability of hemoglobin levels among the municipalities was observed in this study. The combined effect of the explanatory variables contributed to the mean hemoglobin levels up to 0.55 lower and 0.48 higher than the estimated reference mean. This variability of hemoglobin levels was attributable to variables related to access to public goods and services available to the population at the municipal level, such as urbanization and the number of ACS. Likewise, variables of epidemiological importance at the individual level contributed to the variability of hemoglobin levels, such as the child's age, enrollment at daycare centers or kindergarten, being a beneficiary in the Brazilian Income Transfer Program and the nutritional status based on the WAZ index.

Residing in municipalities with a higher urbanization rate had a negative influence on children's hemoglobin levels. This could be explained by the fact that urbanized populations often depend directly on income to obtain food and meet their nutritional requirements; this population also usually makes poor food choices [20,39]. This scenario was evidenced by a study [40] that observed a direct relationship between income and the possibility of choosing food, especially among residents from the urban area. According to its results, having a higher income did not guarantee dietary quality, as a "contradictory" dietary pattern was observed. This pattern was composed of diversified and nutrient-rich food, but also industrialized and ready-to-eat meals, which could compromise the fulfillment of nutritional needs, such as iron intake. In addition, an urbanized population also require greater investments in basic sanitation and health [29]. As shown in the temporal analysis [12], the Brazilian population residing in urban areas is more exposed to factors that contribute to the intergenerational cycle of diminished opportunities, such as unemployment, social inequalities and inadequate access to basic services. These factors can expose these families to nutritional deficiencies, such as lower hemoglobin levels.

Children from municipalities with fewer ACS had lower mean hemoglobin levels when compared to children from municipalities with a higher number of these professionals, especially in the municipalities of quartile 2. The impact of the ACS on the basic health system is already well-known [41,42,43]; but, to our knowledge, this is the first study which shows the possible effect of these workers on the hemoglobin level of children. Therefore, it is suggested that in some municipalities the greater number of ACS may have contributed to improve the health care quality in UBS, reflecting in higher hemoglobin levels. However, it is important to consider that the maximum number of ACS in each municipality is established by a law, i.e., 1 agent per 400 inhabitants [44].

Age was also an important factor to explain the variability in the hemoglobin levels. Children under 24 months of age had the lowest concentrations of hemoglobin as observed in previous studies conducted in other Brazilian locations [45,46]. The age group less than 24 months is considered the most biologically vulnerable to nutritional and infectious diseases. These diseases occur mainly due to the imbalance between nutrient intake to meet nutritional requirements and the little-developed functional immunity [44,47,48]. Therefore, strategies aimed at controlling and preventing nutritional diversions and infections become essential even in places where access to quality food is adequate and health services are considered efficient [18,48].

Although more than half of the children evaluated were not enrolled at daycare centers, higher mean hemoglobin levels were observed among those that were. According to the literature, this positive effect may be associated with a significant improvement in the consumption of healthy food (rich in nutrients for hematopoiesis) at daycare centers [49,50]. On the other hand, a study conducted by Zuffo et al. [45] showed that these institutions have difficulty to meet the children's iron nutritional requirements. Recognizing that early childhood education is the first step towards overcoming poverty [51], our results reinforce the importance of providing high-quality meals by educational institutions.

Unlike studies carried out in different locations [52], this study did not verify the positive effect of the Brazilian Income Transfer Program on the children's hemoglobin levels. In fact, the establishment of a cause-and-effect relationship between the program and hemoglobin levels could not be explained by this cross-sectional study. A possible explanation for this scenario would be the timespan of participation in the Brazilian Income Transfer Program, sometimes too short to observe the effects on children's health [53]. Furthermore, the accomplishment of the conditions of the program [54] or the quality of the services provided [19,53] might not have been sufficient for the prevention and early identification of nutritional deficiencies by biochemical indicators. In addition, families that participate in this program show lower income and greater vulnerability to food deprivation [55] and to nutritional deficiencies [56]. Hence, although the studies show an improvement in the anthropometric indicators of children that are beneficiaries of the program [13,57], their families still live in food and nutritional insecurity scenarios. This could compromise the access to quality food for preventing nutritional deficiencies [58].

According to the WAZ index, a lower mean hemoglobin level was observed in children diagnosed as underweight. This result supports the premise that in the presence of a nutritional deficit scenario, hemoglobin levels are compromised as an adaptive response to food deprivation [59]; however, the cross-sectional design of the study prevents any causal inference. Evidence also suggests that overweight children are subject to decreased hemoglobin levels due to their poor-quality diets [60] and the increased blood volume, iron nutritional requirements [61], pro-inflammatory cytokines and hepcidin [62]. The association between excess body weight and low hemoglobin levels, however, was not observed in this study.

The major strength of our study refers to the use of multilevel analysis to understand the simultaneous influence of the children and municipalities variables on hemoglobin levels. However, our study has limitations that should be considered in the interpretation of our findings and in future research. First, the municipal variables selected for this study constitute a proxy for their development, income distribution, access and quality of public services, and for the possible results of the actions developed under the Brazil Without Poverty Plan. Second, some of these variables represent the situation of the municipalities prior to the implementation of the Brazil Without Poverty Plan, considering the census intervals for the collection of information about the Brazilian population, and therefore might not reflect the scenario to which the children were exposed at the time of the multicenter study. Third, the presented data may not reflect the reality in other municipalities of the same region or other Brazilian regions, even though they were part of the same public policy. Fourth, the sample was not designed to be representative of each municipality individually, but rather of the set of the 16 municipalities in each state. Fifth, we did not investigate the effect of using other supplements on hemoglobin levels in this study. Last, although this study does not allow inference of causality, the findings are a starting point for prospective research that seeks to establish clear and precise relationships between the factors conditioning different levels of determination of nutritional deficiencies in children.

Through the Brazil Without Poverty Plan, 22 million Brazilians have overcome poverty from the income perspective [14]. Considering this and the hemoglobin levels identified by this study, we suggest the possibility of a positive impact from the strategies aimed at the development of human potential in the municipalities included in this public policy, although a proper evaluation of the plan would be required to confirm this.

Conclusions

The variability of children's hemoglobin levels was explained by individual and municipal predictors. These findings reinforce the importance of access to basic public goods and services and the development of policies aimed at reducing social inequalities. The permanence of individuals factors after adjustment for the municipal variables indicates the need for improvement, monitoring and continuity of public policies for the control of nutrient deficiencies in childhood.

Contributors

D. L. F. Silva contributed to data collection, analysis, interpretation of data and drafting the article. D. A. Höfelmann contributed to interpretation of data and for relevant critical review of the final intellectual content and approval of the version to be published. C. A. Taconeli contributed to analysis, interpretation of data and revised the article. R. M. F. Lang, D. C. Tietzmann, J. D. Moreira, S. A. Silva, E. A. F. Nilson, V. S. S. Gonçalves, S. P. Crispim contributed to conception and design of study, analysis and interpretation of data, and for relevant critical review of the final intellectual content and approval of the version to be published. C. Dallazen contributed to conception and design of study, data collect and for relevant critical review of the final intellectual content and approval of the version to be published.

Additional informations

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Acknowledgments

The authors wish to thank the families of the children participating in the study, the Health Secretariats of the participating municipalities, and the State Health Secretariats of Rio Grande do Sul, Santa Catarina and Paraná. Moreover, they wish to thank the researchers who contributed to this study in some aspect: David Gonzalez-Chica, Márcia Regina Vítolo, and Silvia do Amaral Rigon. Inter-American Development Bank, Brazilian General Coordination of Food and Nutrition and Brazilian Graduate Studies Coordinating Board.

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Resumo

Poucos estudos investigaram o efeito simultâneo dos fatores individuais e contextuais sobre a ocorrência da anemia. O estudo procura avaliar a variabilidade dos níveis de hemoglobina em crianças de municípios com vulnerabilidade social e a associação com fatores individuais e municipais. Foi realizado um estudo transversal com dados de crianças de idade pré-escolar (12-59 meses) de um estudo multicêntrico em 48 municípios do Sul do Brasil, incluídos no Plano Brasil Sem Miséria. Os dados dos indivíduos foram coletados com um questionário estruturado, e os dados secundários e ecológicos dos municípios das crianças foram obtidos através de inquéritos nacionais e websites institucionais. O desfecho foi definido como o nível de hemoglobina, obtido com o sistema HemoCue. Foi realizada análise multinível usando modelos lineares generalizados para posição, escala e forma, no R, com nível de 5% de significância . Foram avaliadas 1.501 crianças. O nível médio de hemoglobina foi 12,8g/dL (IC95%: 12,7-12,8), com variabilidade significativa entre os municípios. Níveis de hemoglobina mais baixos foram observados nas crianças em municípios com taxas de urbanização mais altas e menor número de agentes comunitários de saúde, comparado com as categorias de referência. Em nível individual, níveis de hemoglobina mais baixos foram identificados em crianças abaixo de 24 meses, não matriculadas em creches, beneficiárias do Programa Bolsa Família e diagnosticadas com baixo peso. Os resultados destacam fatores importantes nos níveis municipal e individual que estão associados com os níveis de hemoglobina em crianças de municípios com vulnerabilidade social.

Hemoglobinas; Anemia; Criança; Análise Multinível

Resumen

Pocos estudios han investigado el efecto simultáneo de los factores individuales y contextuales en la incidencia de anemia. El objetivo de este estudio fue evaluar la variabilidad de los niveles de hemoglobina en niños socialmente vulnerables en municipios del sur de Brasil y su asociación con factores en el nivel individual y municipal. Se trata de un estudio trasversal con datos de niños (12-59 meses), procedentes de un estudio multicéntrico, realizado en 48 municipios de la región sur de Brasil, incluidos en el Plan Brasil sin Pobreza. Se recogieron los datos de los participantes, usando un cuestionario estructurado, así como datos secundarios y ecológicos de los municipios de los niños, a través de encuestas nacionales y sitios web institucionales. El resultado se definió como el nivel de hemoglobina obtenido por HemoCue. Se realizó un análisis multinivel, usando modelos lineales generalizados para la escala de localización y forma usando R, con un nivel de un 5% de significancia. Un total de 1.501 niños fueron evaluados. La media de nivel de hemoglobina fue 12,8g/dL (95%CI: 12,7-12,8), con una significativa variabilidad entre municipios. Los valores más bajos de hemoglobina se observaron en niños que vivían en municipios con unas tasas más altas de urbanización, y un número de agentes de salud comunitario más bajo, en relación con las categorías de referencia. En el nivel individual, los valores de hemoglobina más bajos fueron identificados en niños con menos de 24 meses, no matriculados en guarderías, beneficiarios de ayudas económicas, enmarcadas en programas de ayuda económica, y diagnosticados como con bajo peso. Los resultados aclararon importantes factores en el nivel municipal e individual que estaban asociados a los niveles de hemoglobina de niños residentes en municipios, así como vulnerables socialmente.

Hemoglobinas; Anemia; Niño; Análisis Multinivel

Submitted on 30/Aug/2019
Final version resubmitted on 23/Apr/2020
Approved on 06/May/2020