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Prevalence and determinants of child undernutrition and stunting in semiarid region of Brazil

Prevalência e determinantes da desnutrição infantil no semiárido do Brasil

ABSTRACT

OBJECTIVE: To analyze the evolution in the prevalence and determinants of malnutrition in children in the semiarid region of Brazil.

METHODS: Data were collected from two cross-sectional population-based household surveys that used the same methodology. Clustering sampling was used to collect data from 8,000 families in Ceará, Northeastern Brazil, for the years 1987 and 2007. Acute undernutrition was calculated as weight/age < -2 standard deviation (SD); stunting as height/age < -2 SD; wasting as weight/height < -2 SD. Data on biological and sociodemographic determinants were analyzed using hierarchical multivariate analyses based on a theoretical model.

RESULTS: A sample of 4,513 and 1,533 children under three years of age, in 1987 and 2007, respectively, were included in the analyses. The prevalence of acute malnutrition was reduced by 60.0%, from 12.6% in 1987 to 4.7% in 2007, while prevalence of stunting was reduced by 50.0%, from 27.0% in 1987 to 13.0% in 2007. Prevalence of wasting changed little in the period. In 1987, socioeconomic and biological characteristics (family income, mother's education, toilet and tap water availability, children's medical consultation and hospitalization, age, sex and birth weight) were significantly associated with undernutrition, stunting and wasting. In 2007, the determinants of malnutrition were restricted to biological characteristics (age, sex and birth weight). Only one socioeconomic characteristic, toilet availability, remained associated with stunting.

CONCLUSIONS: Socioeconomic development, along with health interventions, may have contributed to improvements in children's nutritional status. Birth weight, especially extremely low weight (< 1,500 g), appears as the most important risk factor for early childhood malnutrition.

DESCRIPTORS: Child Health. Malnutrition, etiology. Nutritional Epidemiology. Epidemiology, trends.

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RESUMO

OBJETIVO: Analisar tendências na prevalência e determinantes da desnutrição em crianças na região semiárida do Brasil.

MÉTODOS: Foram analisados dados de duas pesquisas transversais domiciliares de base populacional que utilizaram a mesma metodologia. A amostragem por conglomerados foi utilizada para coletar os dados de 8.000 famílias, do estado do Ceará, Nordeste do Brasil, para os anos de 1987 e 2007. A desnutrição aguda foi calculada como peso/idade < -2 desvios padrão; nanismo como altura/idade < -2 desvios padrão; e emaciação como peso/altura < -2 desvios padrão. Os dados sobre os determinantes biológicos e sociodemográficos foram analisados por meio de análises multivariadas com base em um modelo teórico hierarquizado.

RESULTADOS: Amostras de 4.513 e 1.533 crianças menores de três anos de idade, em 1987 e 2007, respectivamente, foram incluídas nas análises. A prevalência de desnutrição aguda foi reduzida em 60,0%, passando de 12,6% em 1987, para 4,7% em 2007, enquanto a prevalência de nanismo foi reduzida em 50,0%, passando de 27,0% em 1987 para 13,0% em 2007. A prevalência de emaciação teve pouca alteração no período. Em 1987, as características socioeconômicas e biológicas (renda familiar, escolaridade da mãe, disponibilidade de latrina e água potável, consulta médica e hospitalização da criança, idade, sexo e peso ao nascer) foram fatores significativamente associados à desnutrição, ao nanismo e à emaciação. Em 2007, os determinantes da desnutrição ficaram restritos às características biológicas (idade, sexo e peso ao nascer). Apenas uma característica socioeconômica, a disponibilidade de latrina, permaneceu significativamente associada ao nanismo.

CONCLUSÕES: O desenvolvimento socioeconômico, além de intervenções de saúde, parecem ter efetivamente contribuído para a melhoria do estado nutricional das crianças. Peso ao nascer, especialmente o peso extremamente baixo (< 1.500 g), aparece como o fator de risco mais importante para a desnutrição na primeira infância.

DESCRITORES: Saúde da Criança. Desnutrição, etiologia. Epidemiologia nutricional. Epidemiologia, tendências.

INTRODUCTION

Changes in eating patterns and lifestyles resulting from industrialization, urbanization and economic development have contributed to declines in rates of low birth weight and early childhood undernutrition. However, in some regions of the world undernutrition remains a public health problem.^{1,3} In low income countries, more than 50.0% of childhood deaths have undernutrition as the underlying cause,¹¹ mainly due to the high susceptibility of malnourished children to infectious and parasitic diseases. In Asia, excluding China and India, it is estimated that 12.3% of total deaths are related to malnutrition. The highest incidence of child undernutrition occurs within six to 18 months of age in most countries and the deficits acquired at this age are rarely compensated.^{3,14}

In recent decades, Brazil has made substantial improvements in health and nutrition indicators, especially in childhood. However, these improvements occurred unevenly within and among major geographic regions of the country.³ Undernutrition among preschool children declined in the whole country from 1986 to 1996, with a reduction of 51.7% in severe and moderate malnutrition assessed by height-for-age and 12.0% for age-for-weight. However, in 2007, children in Northeast Brazil had the highest weight-for-height (17.9%) and weight-for-age (8.3%) deficits compared with those from the Southern Region (the country's richest region), that were respectively 5.1% and 1.5%.⁵ In Ceará, specific actions and strategies to reduce infant mortality have

been implemented since 1987.² The state launched a situation analysis including cross-sectional population-based studies to monitor major indicators of maternal and child health and nutrition in 1987. These studies, also known as *Pesquisa de Saúde Materno Infantil no Ceará* (PESMIC) described important information in the past decades, allowing for the specific analysis of relevant indicators, such as under-nutrition in childhood.^a

This article aimed to analyze the evolution of the prevalence and determinants of malnutrition in children in the semiarid region of Brazil.

METHODS

Five population-based cross-sectional studies on maternal and child health (PESMICs) surveyed a representative sample of preschool children up to 36 months of age, living in the state of Ceará, Northeastern Brazil, in five data (in 1987, 1990, 1994, 2001 and 2007), using the same methods. For the present article, we used data from 1987 and 2007.

Ceará is one of the poorest states in the country, with a semiarid climate, which covers 95.0% of its territory, and a population of 8.2 million. Its economic development (industry and tourism) is concentrated in the capital, Fortaleza (2.3 million inhabitants), and the Metropolitan area. In the other municipalities of the rural area, subsistence agriculture prevails, with years of harvest alternating with recurrent periods of drought. Social security benefits and government grants (e.g., *Bolsa Família* program)^b provided to families have become a more stable source of income for the population of the rural area, substantially ensuring the functioning of the economy of this region.

The study applied the technique of cluster sampling, using Brazilian Institute of Geography and Statistics (IBGE) census tracts and stratification between the capital Fortaleza and the rural area. Census tracts result from the division of each municipality in geographic areas with variable extensions, but with uniform population (about 300 families). The sample size was calculated as 8,000 households, representing about 35,000 people, 11,000 women aged between 12 and 49 years and 2,000 children under 3 years of age. It was initially established in 1986 for the first study, to estimate the infant mortality rate in the state of Ceará, and was maintained in subsequent years. The initial sample size was multiplied by a correction factor equal to 2, covering the design effect¹ of cluster sampling. Furthermore, the sample was increased by 10.0% to compensate for losses.

To ensure the representativeness of the study population, the selection of municipalities, census tracts and households was done randomly, following a process of multistage sampling: a) drawing of 40 municipalities, 13 in the metropolitan area of Fortaleza (1/3 of the population) and 27 in the rural area. The selection of municipalities was performed systematically according to their population weight from a list sorted by region, sequenced to ensure appropriate geographic distribution. From this process, a large city might be drawn more than once, and its weight observed in the sample population. Thus, Fortaleza was selected more than once and the others once each; b) In each county, 10 census tracts in urban and rural areas were randomly selected, thus allowing all areas, even the most remote, to be represented. In Fortaleza, 100 census tracts were randomly selected; c) Once a census tract was defined, and its corresponding map obtained from the IBGE, the location of the cluster of 20 houses to be investigated was defined. The starting point of the cluster, the first home to be visited, was selected randomly. Households were visited in a row, following specific rules: the direction of movement/travel was counterclockwise; shops and uninhabited buildings were excluded and replaced with occupied buildings; in case of missing families, up to three return visits were conducted in an attempt to obtain data; in each household, all resident children in the relevant age group had their anthropometric measurements taken and we obtained other information from their caregivers.

To assess children's nutritional status we used three anthropometric indicators: weight-for-age (W/A), height/length-for-age (H/A) and weight-for-height (W/H). They were compared with those of an international reference population, defined by the National Center for Health Statistics (NCHS-US), according to WHO recommendations,¹⁶ and deficits found classified children as follows: undernutrition, $W/A < -2$ standard deviation (SD); stunting, $H/A < -2$ SD; wasting, $W/H < -2$ SD.

In addition, data on socioeconomic and demographic features, utilization of health care, including hospitalization and history of main childhood diseases (i.e., diarrhea and pneumonia) were collected on children and their families. Those variables appearing in the conceptual model (Figure) were analyzed and included: socioeconomic and demographic characteristics (family income, availability of water, availability of toilets); child care (breastfeeding, father living with the family, mother's education); health care (child possesses a health card, medical consultation, immunization); biological characteristics (age, sex, birth weight), history of morbidity (hospitalization for diarrhea, hospitalization for pneumonia).

^a Correia LL, Silveira DMI, Campos JS, organizadores. Quarta pesquisa de saúde materno-infantil no Ceará (Pesmiv IV): resultados comparativos do período 1987-2001. Fortaleza: Secretaria de Saúde do Estado do Ceará; 2003.

^b Ministério do Desenvolvimento Social e Combate à Fome. *Programa Bolsa-Família*. Brasília (DF); 2013 [cited 2013 Oct 23]. Available from: <http://www.mds.gov.br>

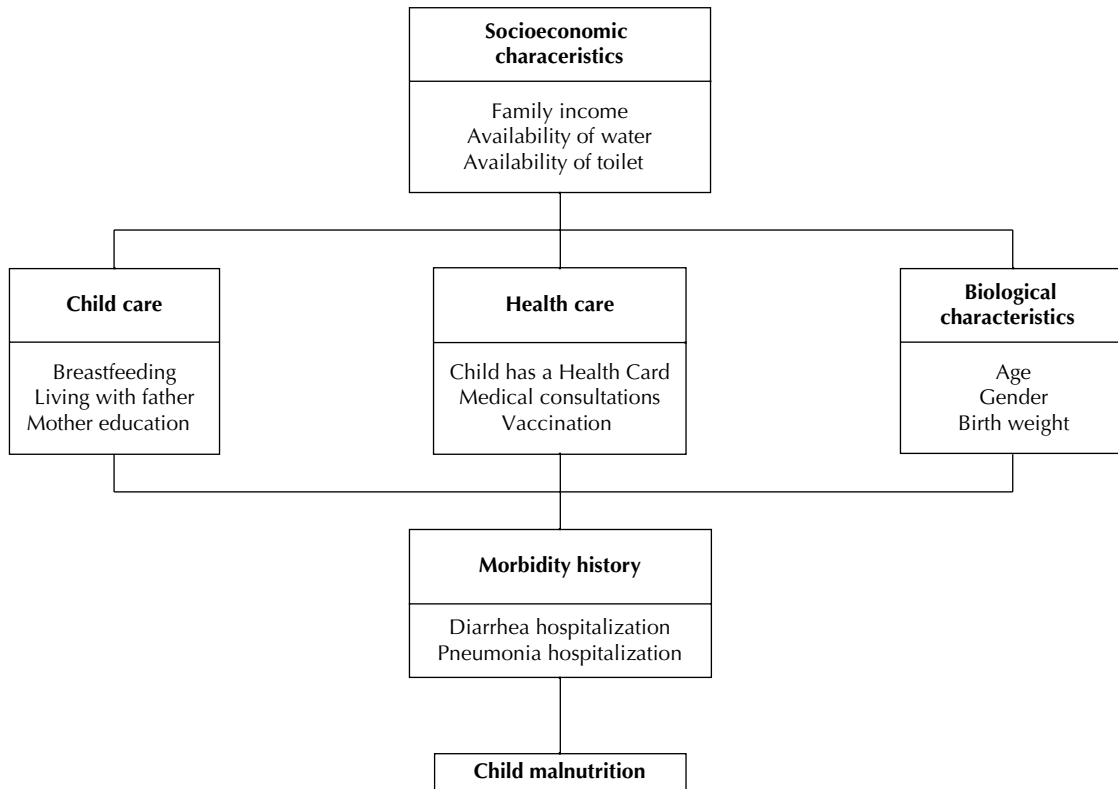


Figure. The theoretical conceptual model used in the analysis.

Information was collected from August to November 1987 and from July to December 2007 using three questionnaires. The first recorded general information for each selected household, the second, information related to mothers, and the third, to the child. The questionnaires were reviewed daily by field supervisors to identify and correct errors whenever possible. During the fieldwork, a subsample of 10.0% of children was weighed and their heights measured again by supervisors blinded to measurements recorded earlier for quality control. Weight was measured using portable electronic scales, Tanita® type, with a capacity of 150 kg and 0.1 kg calibration. Height was measured with a portable scale with a range from 30 to 110 cm, with precision of 1 mm. Children aged under 24 months were measured horizontally and those between 24 and 35 months in a standing position. The equipment was calibrated regularly, using standardized measures, early in the day and after every 25 measurements. The research technical team comprised a coordinator and three field work teams, each with a supervisor and eight evaluators/interviewers who had a graduate degree in nutrition, nursing or social services. The evaluators worked in pairs, each covering a sector (cluster of 20 homes) per day.

Data were entered twice using EpiInfo 2000 and analyzed using SPSS 14 for Windows, with the Anthro

program used to analyze the anthropometric data. The initial analysis consisted of tabulating the frequency distributions of all variables according to nutritional status. The prevalence ratio (PR) was estimated, equivalent to the ratio of cumulative incidence in cohort studies. The Likelihood ratio test with two-tailed significance was used to assess the statistical significance of associations. Cox proportional hazards regression was used to investigate whether the strength of association found in the bivariate analysis was significantly affected by the presence of possible confounding variables. Assuming a constant period of risk, the Cox model can be adapted to estimate PR in cross-sectional studies² and in these studies this measure seems to produce better estimates of risk than the odds ratio.^{2,17} Multivariate analysis was conducted using a hierarchical strategy, based on a conceptual model¹² (Figure). The modeling process included, stratum by stratum, all the variables determined by the conceptual model, in a backward manner, and kept those with a *p* value less than 5%.

RESULTS

There was a decrease in the absolute number of children under three years of age found in the 8,000 households surveyed in each study year, which fell from 4,513 (1987) to 1,533 (2007). The prevalence of undernutrition was reduced by 60.0%, from 12.6% (1987) to

4.7% (2007). Stunting showed a reduction of 50.0%, from 27.0% in 1987 to 13.0% in 2007. The prevalence of wasting was low throughout the years, below 2.0%, but showed a considerable increase in the last survey reaching 3.5% (Table 1).

Biological, socioeconomic, demographic and health characteristics of children and their families are shown in Table 2. The distribution of children in the sample by gender and age groups showed small variations. There was a tripling of the proportion of children with very low birth weight (birth weight < 1,500 g), which increased from 0.7% in 1987 to 2.1% in 2007. The prevalence of low birth weight (< 2,500 g) declined slightly from 10.9% to 8.3%. The BCG vaccine coverage increased from 52.0% to 88.0%, and rates of hospitalization for pneumonia and diarrhea remained almost unchanged. The illiteracy rate fell from 41.6% to 9.4% among mothers. Sanitation (toilet availability) rates increased from 13.3% to 57.5%. The proportion of households that reported income below the minimum wage in 2007 was 20.0% lower than the percentage recorded in 1987.

We observed that in 1987 undernutrition was significantly associated with age over six months, low birth weight (< 2,500 g), non-availability of toilets in the household, maternal illiteracy, and family income below the minimum wage. In 2007, while the biological factors remained as determinants of undernutrition, socioeconomic factors did not. Compared to 1987, the biological factors showed interesting variations. Regarding age, there was a reduction in the risk of undernutrition in children above two years old, which declined from 4.3 in 1987 to 2.7 in 2007. It is worth noting that in 2007, the risk of undernutrition associated with age was significant only for this age group above two years, while in 1987 younger children (aged 7 to 24 months) also had a high risk of undernutrition (Table 3).

The converse is true for low birth weight, with the risk of undernutrition for low birth weight children compared to those born with normal weight being much higher in 2007 compared to 1987, especially for very low birth

weight, which rose from 2.9 in 1987 to 9.9 in 2007. In 1987, male sex was not among the determinants of acute malnutrition but in 2007 boys had a 70.0% increased risk of undernutrition, compared to girls.

It was observed that stunting in 1987 was associated with the same biological and socioeconomic factors observed for undernutrition, together with factors related to child care, (immunization and hospitalization for pneumonia). Thus, children not vaccinated with BCG had a 32.0% greater risk of having chronic malnutrition than children who had received this vaccine. Also, children who had developed severe pneumonia requiring hospitalization in the 12 months preceding the study, had a 45.0% higher risk of stunting than children who had not been hospitalized. In 2007, stunting was associated with only two factors, the non-availability of toilets at home, an indicator of socioeconomic status, which also reflects the precarious hygienic state of the family and points to a severe state of poverty, and low birth weight a biological factor (Table 4).

In 1987, wasting was associated with age, income, toilet availability and birth weight, as well as undernutrition and stunting, in addition to female sex, lack of tap water at home and no medical consultation in the previous three months. In 2007, wasting was strongly associated with birth weight, showing a gradient of risk that led children born weighing less than 1,500 g to present a 25.0% higher risk of being emaciated, compared with children born within the normal weight parameters (Table 5).

Factors such as feeding patterns, parental presence at home and availability of 'child health card', showed no significant association with any child malnutrition indicator in either analyzed period. The associations found in 1987 for undernutrition were income, mother literacy, toilet availability, age, birth weight, and in 2007 the variables significantly associated were age, sex and birth weight. For stunting, they were income, mother literacy, toilet availability, age, BCG vaccination, hospitalization in 1987 and toilet availability and birth weight in 2007.

Table 1. Evolution of the prevalence of undernutrition, stunting and wasting in children under three years of age. Ceará, 1987-2007.

Indicator Year	Undernutrition ^a		Stunting ^b		Wasting ^c	
	%	95%CI	%	95%CI	%	95%CI
1987 (N = 4,513)	12.6	11.6;13.6	27.0	25.7;28.3	1.9	1.5;2.3
1990 (N = 2,795)	9.6	8.5;10.6	21.0	19.5;22.5	1.8	1.3;2.3
1994 (N = 2,453)	9.1	8.0;10.2	17.9	16.4;19.4	0.9	0.5;1.2
2001 (N = 1,697)	4.1	3.2;5.1	10.8	9.3;12.3	1.5	0.9;2.2
2007 (N = 1,533)	4.7	3.6;5.8	13.0	11.2;14.8	3.5	2.5;4.6

^a Z-score for weight for age < -2 standard deviations

^b Z-score of height for age < -2 standard deviations

^c Z-score of weight for height < -2 standard deviations

Table 2. Distribution of biological, socioeconomic and health characteristics of children under three years of age.^a Ceará, Northeastern Brazil, 1987 and 2007.

Year/Characteristic	1987 (N = 4,513) %	2007 (N = 1,533) %
Child age (in months)		
0-6	18.5	21.0
7-12	15.6	16.6
13-24	33.7	34.8
25-36	32.2	27.6
Gender		
Male	50.2	57.4
Female	49.8	42.6
Birth weight		
Very low (< 1,500 g)	0.7	2.1
Low (< 2,500 g)	10.2	6.2
Normal (≥ 2,500 g)	89.1	91.7
BCG vaccination (up to 36 months)		
Yes	52.2	88.3
No	47.8	11.7
Pneumonia hospitalization (previous 6 months)		
No	96.7	96.6
Yes	3.3	3.4
Diarrhea hospitalization (previous 12 months)		
No	95.7	98.2
Yes	4.3	1.8
Mother knows how to read		
Yes	58.4	90.6
No	41.6	9.4
Family income (monthly)		
< Minimum wage	47.5	37.9
≥ Minimum wage	52.5	62.1
Toilet availability		
Yes	13.3	57.5
No	86.7	42.5
Place of residence		
Capital	18.8	29.4
Rural	81.2	70.6

^a All variables presented highly statistical significance ($p < 0.001$) as differences between 1987 and 2007 were compared (Chi-square test).

Finally, for wasting the associations were income, toilet and tap water availability, age, sex, medical consultation, birth weight in 1987 and sex and birth weight in 2007.

DISCUSSION

We observed a reduction of 60.0% and 50.0% in the prevalence of undernutrition and stunting, respectively, in children less than three years of age over the 20 year study period, i.e., 1987-2007. On the other hand, wasting increased in the last survey (2007), although its

prevalence has always been traditionally low. Important changes occurred in the characteristics of the study population and with the factors associated with undernutrition, stunting and wasting in childhood in the 20-year period.

Substantial declines in the prevalence of child malnutrition have previously been documented in Brazil from the comparison of national surveys.^{4,11} The "Demographic Health Surveys"¹¹ for the period from 1996 to 2007, included 4,000 children under five years and showed a decline of approximately 50.0%. This was attributed to a combination of strong increases in purchasing power

Table 3. Adjusted prevalence rate ratios (PRR)^a and 95% confidence intervals (CI) of undernutrition (Z-score for weight for age < -2 standard deviations) in children under three years of age, according to selected variables. Ceará, Northeastern Brazil, 1987 and 2007.

Variable	1987		2007	
	PRR	95%CI	PRR	95%CI
Family income (month)				
≤ 1 minimum wage	1.394		1.201	0.710;2.032
> 1 minimum wage	1	1.04;1.87	1	
Mother knows how to read				
Yes	1		1	
No	1.98	1.47;2.65	2.109	0.658;6.672
Toilet availability				
Yes	1		1	
No	1.77	1.04;3.03	0.812	0.463;1.426
Child age (in months)				
0 to 6	1		1	
7 to 12	3.50	1.82;6.75	1.35	0.51;3.61
13 to 24	3.56	1.93;6.56	1.11	0.50;2.59
25 to 36	4.32	2.35;7.94	2.69	1.23;5.90
Gender				
Male	0.812	0.463;1.078	1.69	1.02;2.81
Female	1		1	
Birth weight				
Very low (< 1,500 g)	2.88	1.06;7.81	9.88	4.76;20.50
Low (< 2,500 g)	2.21	1.57;3.12	3.14	1.58;6.27
Normal (> 2,500 g)	1		1	

^a Adjusting for the following variables: income, source of water used for drinking, sanitation, whether it was breastfed, mother's education, if the parent resides in the same house as the child, if child has a health card, whether a physician had been consulted in last three months, if it was vaccinated for BCG, age, sex, birth weight, origin and hospitalizations for diarrhea and pneumonia.

of families and expansion of the population's access to essential public services, especially with the expansion of the Family Health Strategy in almost all Brazilian states.¹¹ The recent trend of improvement in income distribution and poverty reduction in Brazil is a consequence of the revival of economic growth and the consequent decrease in unemployment, increases in minimum wage above inflation and the strong expansion of coverage of income transfer programs, e.g., *Bolsa Família* program.^{5,7}

In Ceará, several strategies and interventions implemented during the 20-year study period contributed to the reduction of malnutrition. One of those was the creation of the Community Health Agent Program in the 1990s, when mothers and children began to be visited at home monthly by community health workers.⁵ During these home visits, they were weighed, measured and referred to a health unit if any abnormality was identified. Through this routine and periodic process, it became possible to identify children who presented

with some degree of malnutrition and intervene with prophylactic and therapeutic measures.^{7,15}

In 1987, indicators of child malnutrition were significantly associated with several variables related to child's characteristics, to health care, and to the socioeconomic conditions of the family, namely, being aged above six months, female sex, low birth weight, no medical consultation in the previous three months, hospitalization due to pneumonia in the previous six months, no immunization with BCG, non-availability of tap water and toilet at home, maternal illiteracy, and family income below one minimum wage.

In 2007, while the biological variables (age, sex and birth weight) remained determinants of malnutrition, variables related to socioeconomic status, childhood morbidity and access to health care entirely lost association, with exception of toilet availability, which remained significantly associated with the height for age indicator. Overall, the role of low birth weight as a determinant of child malnutrition, chronic or acute,

Table 4. Adjusted prevalence rate ratios (PRR)^a with 95% confidence intervals (CI) of stunting (Z-score of height for age < -2 standard deviations) in children under three years of age, according to selected variables. Ceará, Northeastern Brazil, 1987 and 2007.

Variable	1987		2007	
	PRR	95%CI	PRR	95%CI
Family income (month)				
≤ 1 minimum wage	1.15	0.96;1.38	1.285	0.935;1.765
> 1 minimum wage	1		1	
Mother knows how to read				
Yes	1		1.194	0.672;2.120
No	1.68	1.40;2.02	1	
Toilet availability				
Yes	1	1	1	1
No	2.16	1.52;3.06	1.35	1.00;1.81
Child age (in month)				
0 to 6	1	1	1	
7 to 12	1.95	1.32;2.89	1.013	0.566;1.814
13 to 24	3.23	2.31;4.52	1.352	0.855;2.139
25 to 36	3.09	2.19;4.36	1.318	0.814;2.134
BCG vaccination (up to 36 months)				
Yes	1		1	
No	1.32	1.1;1.59	1.077	0.467;2.484
Pneumonia hospitalization (previous 6 months)				
No	1		1	
Yes	1.45	1.01;2.08	0.511	0.187;1.398
Birth weight				
Very low (< 1,500 g)	2.594	1.371;4.908	4.183	2.457;7.121
Low (< 2,500 g)	1.565	1.232;1.989	1.544	0.922;2.588
Normal (> 2,500 g)	1		1	

^a Adjusting for the following variables: income, source of water used for drinking, sanitation, it was breastfed, the state school of the mother if the father lives in the same household as the child, if child has a health card, whether a physician had been consulted in last three months, if it was vaccinated for BCG, age, sex, birth weight, origin and hospitalizations for diarrhea and pneumonia.

increased in the twenty years span, especially due to the increased survival rates of children born with very low birth weight (below 1,500 g), which accounted for significant excess of risk.

From 2000 to 2007, 15.0% of children were born with low birth weight (< 2.5 kg) in the world, and it is an underlying factor for 60.0%-80.0% of neonatal deaths,⁶ especially in less developed countries.^{5,12} Several studies show that children born with extremely low birth weight are at high risk for neurological abnormalities and delayed growth and development in the first years of life.¹⁴

The reduction of child malnutrition in Ceará over the past two decades is an important achievement for the health and well-being of the state's population. However, in order to maintain and further improve the nutritional status of children in Ceará, it will be

necessary to maintain and enhance the interventions and policies that have contributed to these improvements, especially those that have favored an increase in purchasing power of the poorest population groups. Public policies should continue to ensure investments aimed at completing the universalization of the Brazilian population's access to essential services such as education, health care and sanitation.

We emphasize the significant role that these maternal and child health epidemiologic studies have had in allowing a scientific examination and understanding of the factors associated with the nutritional status of children in the state of Ceará. It is essential to guide the development, monitoring and evaluation of social and health strategies and programs aimed at addressing child malnutrition at the state level.

Table 5. Adjusted prevalence rate ratios (PRR)^a and 95% confidence intervals (CI) of wasting (Z-score of weight for height < -2 standard deviations) in children under three years of age, according to selected variables. Ceará, Northeastern Brazil, 1987 and 2007.

Variable	1987		2007	
	PRR	95%CI	PRR	95%CI
Family income (monthly)				
≤ 1 minimum wage	9.28	5.60;15.38	1.28	0.33;4.96
> 1 minimum wage	1		1	
Had a medical appointment				
Yes	1		1	
No	3.88	2.27;6.62	1.30	0.34;4.97
Toilet availability				
Yes	1		1	
No	2.71	1.35;5.40	1.08	0.27;14.25
Child age (in months)				
0 to 6	1		1	
7 to 12	2.94	1.67;5.18	0.83	0.21;3.22
13 to 24	3.69	1.53;8.87	1.19	0.19;7.31
25 to 36	3.85	1.49;9.95	3.97	0.31;50.65
Gender				
Male	0.27	0.15;0.50	0.29	0.10;0.83
Female	1		1	
Has access to piped water				
No	2.56	1.42;4.63	2.71	0.23;31.55
Yes	1		1	
Birth weight				
Very low (< 1,500 g)	0		24.86	12.71;48.62
Low (< 2,500 g)	1.124	0.46;2.74	7.33	1.61;33.42
Normal (≥ 2,500 g)	1		1	

^a Adjusting for the following variables: income, source of water used for drinking, sanitation, whether it was breastfed, mother's education, if the parent resides in the same house as the child, if child has a health card, whether a physician had been consulted in last three months, if it was vaccinated for BCG, age, sex, birth weight, origin and hospitalizations for diarrhea and pneumonia.

Our study has important advantages over previous ones given that it is population-based and uses the same methods in different periods, with the same sample representation allowing for the evaluation of child malnutrition in the same region within a 20-year period.

Some study limitations should also be noted. First, we used a theoretical model based only on available variables. Second, the cross-sectional nature of the study design only allows examination of associations and in some of these it is impossible to rule out reverse causality, as in income and maternal education. Nevertheless, the study shows important trends that should be used in the formulation of other studies and planning health actions and interventions.

Finally, it is important that investments continue to be made to conduct these periodic epidemiologic maternal

and child health studies, since they have proven to be invaluable in providing a scientific assessment of the nutritional status and health of children, enabling the comparison of indicators and associated factors over time. Preventive measures and actions aimed at further reducing and/or controlling factors associated with health and nutritional status of children may contribute to further improving child health and nutrition in Ceará, and consequently the achievement of the Millennium Development Goals.

This study showed a decline in child malnutrition and an increase in the survival rates of very low birth weight children in the 20-year period. In 1987, socioeconomic and biological characteristics (income, mother's education, sanitation, age, birth weight) were associated with the nutritional indicators. In 2007, the determinants of malnutrition were

restricted to biological characteristics (age, sex and birth weight). The results suggest that socio-economic development, along with health interventions, contributed to improve children nutritional status in the study period.

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The authors declare that there are no conflicts of interest.