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Millennium Development Goals: the impact of healthcare interventions and changes in socioeconomic factors and sanitation on under-five mortality in Brazil

Objetivos de Desenvolvimento do Milênio: impacto de ações assistenciais e mudanças socioeconômicas e sanitárias na mortalidade de crianças

Objetivos de Desarrollo del Milenio: impacto de acciones asistenciales y cambios socioeconómicos y sanitarios en la mortalidad de niños

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Abstract

The United Nations approved the Millennium Development Goals (MDGs) in 2000, including Target 4.A, or a two-thirds reduction in under-five mortality by 2015. Brazil reached this target in 2010. The current study aimed to analyze the trend in under-five mortality and the correlation with healthcare, socioeconomic, and sanitation indicators in Brazil's major geographic regions that helped the country meet the MDGs. This was an ecological study using secondary data for Brazil according to Intermediate Urban Linkage Regions (RIAU in Portuguese) from 2001 to 2017. Analyses of tendencies were performed with joinpoint *and multiple linear regression models. The study showed a downward trend in the under-five mortality rate during the periods studied, with the largest statistically significant change from 2001 to 2010 (AAPC = -3.95; 95%CI: -4.3; -3.6), the lowest changes from 2011 to 2015 (AAPC = -2.35; 95%CI: -3.7; -1.0), and stabilized rates in 2016 and 2017 (AAPC = -0.07; ICC = -4.2; +4.3). Low income (extreme poverty) in the children's families and absence of maternal schooling were the variables most closely correlated with under-five mortality rate (r = 0.649, p < 0.001 and r = 0.640, p < 0.001, respectively). The fact that Brazil met the fourth target in the MDGs reflected the country's progress in reducing the under-five mortality rate, but the data suggest the rate's possible stabilization in recent years. Meanwhile, social and healthcare indicators revealed the importance of this reduction, challenging the country to maintain and further improve its public policies in this area.*

Health Status Disparities; Child Health; Mortality

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Introduction

The Millennium Development Goals (MDGs) were approved in 2000 by the United Nations General Assembly, with 191 signatory countries, as guidance for reducing extreme poverty by the year 2015. The fourth of the eight proposed goals referred to a two-thirds reduction in under-five mortality in relation to the rate in 1990 [1]. The rationale for this target is that the neonatal period concentrates the largest share of deaths in children under 5 years, with a reduction in survival at the youngest ages [2].

According to data from the United Nations (UN), the first day, week, and month of life are the most critical periods for infants' survival. In 2015, of the 5.9 million children that died before reaching age 5 years, approximately 1 million died on the day they were born, another 1 million in the first week of life, and some 2.8 million during the first 28 days of life [3]. The higher the rate of death in the first 6 days of life, the more complex is intervention in the causes of deaths. This highlights the importance of developing health measures and health services in prenatal, childbirth, and postpartum care [1].

Infant mortality (under 1 year of age) and under-five mortality have been considered highly relevant indicators of a country's health and living conditions, due to the vulnerability to social, health, and economic determinants [4]. These feature environmental conditions, demographic factors, socioeconomic conditions, nutritional status, and factors related to the care itself that have contributed to the epidemiological transition and thus to the profile of the main causes of death, as well as to their avoidability [5,6].

These factors motivated a concerted global effort to reach the MDGs. In the 1990s, the world was witnessing 90 under-five deaths per 1,000 live births. By 2015, global efforts had brought the figure down to 43 deaths per 1,000 live births, a reduction of 52.2% in under-five mortality [3]. In Brazil, these indicators reached the proposed target in 2010. In 1990, the under-five mortality rate was 59.6 per 1,000 live births, so two-thirds of this figure represents a reduction of 39.7 per 1,000 live births, the equivalent of a rate of 19.9 per 1,000 live births. The revised under-five mortality rate for 2010 was 19.4 per 1,000 live births, below the target [7]. However, the levels are still high, given the huge challenges Brazil faces in this area, including disparities between regions and social groups and the precarious care for mothers and newborns.

In the 2015, the under-five mortality rate in Brazil was 15.6 per 1,000 live births. This level represented a major drop that was due mainly to the decline in infant mortality (first year of life), from 47.1 per 1,000 live births in 1990 to 13.5 per 1,000 live births in 2015. That same year, deaths in the neonatal component (0 to 27 days of life) accounted for 70% of the infant deaths, 54% of which occurred in the first week of life [8].

These results were influenced by the healthcare provided through the Brazilian Unified National Health System (SUS), which has succeeded in narrowing the health inequalities, with improvements in coverage and access to health services throughout the country. The SUS provides universal and comprehensive healthcare to the entire Brazilian population, free of cost, integrated, decentralized, and with community participation [9].

The UN and the World Health Organization (WHO) also emphasize the need for a combination of strategies together with the SUS itself, backed by policies, programs, and actions in different areas and increased access and healthcare coverage in the improvement of these indicators [3]. Such policies, programs, and actions feature the Statute of Children and Adolescents (ECA); the Bolsa Família Program; the Family Health Strategy (FHS); the More Doctors Program; the National Policy for Humanization of Labor and Birth; the Stork Network, with guidelines of care for labor, childbirth, growth, and development; and the National Policy for Comprehensive Care for Children (PNAISC, in Portuguese) [10]. In addition, for several years the literature has pointed positively to the use of public policies focused on improvement of access to prenatal care, water supply, and sanitation as strategies to fight infant and under-five mortality [11].

There is thus a need to maintain the progress achieved in reducing under-five mortality and to focus on meeting the commitment made to the global struggle against infant mortality through the Sustainable Development Goals (SDGs), aimed at reducing neonatal mortality to 12 per 1,000 live births or lower and under-five mortality to 25 per 1,000 live births or lower in the world by 2030. In addition, there is still a lack of clarity on which actions actually have the greatest impact in reducing under-five mortality. Such knowledge is crucially important at this moment, when evidence points

to worsening of some indicators since 2016, alongside the resurgence of diseases that had been considered eradicated.

The current study thus aims to analyze the trend in under-five mortality rates in Brazil from 2001 to 2017 and the correlation with healthcare, socioeconomic, and sanitation indicators in Brazil's major geographic regions and that helped the country meet the MDGs.

Methods

This is an ecological study whose units of analysis are Intermediate Urban Linkage Regions (RIAU in Portuguese), proposed by the Brazilian Institute of Geography and Statistics (IBGE). A RIAU consist of a group of municipalities (counties) with a hub city that exerts influence in macroregional terms, characterized by internal linkage, based on supply and demand for high-complexity goods and services. Based on these criteria, Brazil was divided into three distinct regionalization models, the Expanded Urban Linkage Regions, consisting of 14 territories; the RIAU, with 161; and the Immediate Urban Linkage Regions, with 482 [12].

For analysis of the target phenomenon, we chose the RIAU as the unit, given the complexity and inequality in population distribution across Brazil's territory. In this sense, in order to stabilize the data and avoid outlying numbers, the indicators are aggregated for the 161 regions.

The data collection covered all of Brazil's municipalities. The data for composing the indicator "under-five mortality rate" were collected for the period from 2001 to 2017 (outcome variable). For healthcare (prenatal appointments, childcare, medical appointments in infants, medical appointments in children 1 to 4 years of age, nurse visits, medical visits), and sanitation conditions (proportion of households connected to the public water system, proportion of households with open-air sewage, proportion of households connected to the sewage disposal system) were collected from 2001 to 2005 and from 2011 to 2015. Data on schooling (proportion of illiterate women over 15 years of age) and income (percentage of children in families with low income) refer to the years 2000 and 2010.

All the data were obtained from the webpage of the Health Informatics Department (DATASUS) and generated continuous quantitative variables, as shown in Box 1. Data collection and analysis were done from April to July 2019. The indicators were built with a weighted mean of the municipalities' data for each RIAU. This strategy was used in the attempt to reduce the discrepancies that might emerge in these new indicators in case cities with different population sizes had the same weight in the determination of the final indicator.

In order to assess the trend in under-five mortality from 2001 to 2017, we used the Joinpoint statistical package, version 4.6.0.0 (http://surveillance.cancer.gov/joinpoint/), which performs the annual percentage change (APC) estimates in a segmented linear regression (joinpoint regression), identifying possible turning points. The alterations in the increase or decrease in the mortality rates are reflected in each turning point [13]. Significance tests are based on the Monte Carlo permutation method with $p < 0.05$ and calculation of the rate's annual percent change, using the rate's log [14].

To analyze the correlation between under-five mortality rate and socioeconomic, sanitation, and healthcare variables, we used Pearson's correlation test and proposed multiple linear regression models. These analyses used the periods from 2001 to 2005 and 2011 to 2015 for both the outcome variable and the sanitation and healthcare conditions. Since the data were from the *Demographic Census*, the schooling and income variables were from the years 2000 and 2010. Based on this logic, we opted to exclude the period from 2006 to 2010, since there were no census data for those variables and since they considerably influenced the construction of the final models. Pearson's correlation allowed identifying the existence and size of correlations between the dependent variable (under-five mortality) and independent variables for each period. Strength of correlations was classified as: $r < 0.30$, weak correlation; $0.30 < r < 0.70$, moderate correlation; and $r > 0.70$, strong correlation [15].

Finally, we proposed multiple linear regression models for each of the periods analyzed. After analysis of the correlation matrix, we verified the presence of collinearity between the variables "percentage of children in households earning up to 1/4 minimum wage" and "Proportion of illiterate women over 15 years of age". We thus opted to include the variable "women's schooling" in the multiple linear regression model. After proceeding to the multiple analysis, we verified the assump-

Box 1

Calculation of under-five mortality, healthcare, socioeconomic, and sanitation conditions. Intermediate Urban Linkage Regions (RIAU), Brazil, 2001 to 2015.

	Indicator	Calculation	Data source
Mortality	Under-five mortality rate	Total deaths in children under 5 years living in the RIAU in the period/ total live births in the RIAU in the same period x 1,000	DATASUS → Tabnet → Vital Statistics; Mortality – 1996 to 2017, ICD-10 → Overall Mortality → Deaths According to Residence (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/obt10br.def, accessed on 05/Apr/2019) DATASUS → Tabnet → Vital Statistics → Live Births – 1994 to 2017 → Live Birth → Births According to Mother's Residence (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sinasc/cnv/nvbr.def, accessed on 05/Apr/2019)
Healthcare Actions	Prenatal appointments	Total prenatal visits in the RIAU during the period/total pregnant women registered in the RIAU in the same period	DDATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Prenatal Care (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care: Family Health,1998 to 2015 → Health Status → Number of Pregnant Women (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABSbr.def, accessed on 02/May/2019)
	Childcare appointments	Total childcare appointments (medical plus nursing appointments) in the RIAU in the period/total number of children under 5 years registered in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Childcare Appointments (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → Females <1 year/Males <1years/ Females 1 to 4 years/Males 1to 4 years (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
	Medical appointments in children under 1 year	Total medical appointments in children under 1 year in the RIAU in the period/total number of children under 1 year registered in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Appointments < 1 year (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → Females < 1 year/Males < 1 year (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
	Medical appointments in children 1 to 4 years of age	Total medical appointments in children 1 to 4 years of age in the RIAU in the period/total number of children 1 to 4 years of age registered in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Appointments1 to 4 years (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → Females 1 to 4 years/Males 1 to 4 years (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
	Nurse visits	Total nurse visits in the RIAU in the period/total number of families registered in basic healthcare in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Nurse Visits (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → No. Families (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, aceessed on 08/Jun/2019)

(continues)

Box 1 (continued)

	Indicator	Calculation	Data source
Healthcare Actions	Medical visits	STotal medical visits in the RIAU in the period/total families registered in basic healthcare in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Care → 1998 to 2015 → Production and Markers → Medical Visits (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABPbr.def, accessed on 02/May/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → No. Families (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
Sanitation	Proportion of households with running water	STotal households with running water in the RIAU in the period/ total families registered in basic healthcare in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Sanitation Conditions → Running Water (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABCbr.def, accessed on 03/Jul/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → No. Families (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
	Proportion of households with open-air sewage	Total households with open-air sewage in the RIAU in the period/ total families registered in basic healthcare in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Sanitation Conditions → Open-air Sewage (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABCbr.def, accessed on 03/Jul/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → No. Families (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
	Proportion of households with sewage disposal	Total households with sewage disposal in the RIAU in the period/ total families registered in basic healthcare in the RIAU in the same period	DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Sanitation Conditions → Sewage Disposal (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABCbr.def, accessed on 03/Jul/2019) DATASUS → Tabnet → Healthcare → Basic Care → Family Health, 1998 to 2015 → Family Registry → No. Families (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?siab/cnv/SIABFbr.def, accessed on 08/Jun/2019)
Schooling	Proportion of illiterate women over 15 years of age	Number of illiterate women 15 years or older (cannot write a simple note in their mother tongue) in the RIAU in the study year/female population over 15 years in the RIAU in the same study year	DATASUS → Tabnet → Demographic and Socioeconomic Data → Education, 1991, 2000, and 2010 Censuses → Illiteracy Rate → Population 15 years or older (Female) (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?ibge/censo/cnv/alfuf, accessed on 03/Jul/2019) DATASUS → Tabnet → Demographic and Socioeconomic Data → Resident Population → Censuses (1980, 1991, 2000, and 2010), Population Count (1996), and inter-census projections (1981 to 2012), according to age bracket, sex, and household situation; Resident Population (15 years or older) (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?ibge/cnv/popuf.def, accessed on 03/Jul/2019)

(continues)

Box 1 (continued)

	Indicator	Calculation	Data source
Income	Percentage of children from low-income families	Number of children under 14 years in households with per capita income under 1/4 minimum wage in RIAU in the study year / resident population of children under 14 years in the RIAU in the same year x 100	DATASUS → Tabnet → Demographic and Socioeconomic Data → Work and Income, Censuses, 1991, 2000, and 2010; Proportion of children in low-income households, < 1/4 Minimum Wage (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?ibge/censo/cnv/crianpobrbr, accessed on 03/Jul/2019) DATASUS → Tabnet → Demographic and Socioeconomic Data → Work and Income, Censuses, 1991, 2000, and 2010 → Children (under 14 years) (http://tabnet.datasus.gov.br/cgi/deftohtm.exe?ibge/censo/cnv/crianpobrbr, accessed on 03/Jul/2019)

DATASUS: Health Informatics Department.

tions: absence of multicollinearity, normality of residuals, homoscedasticity of residuals, and absence of serial autocorrelation. From the bivariate analysis and inclusion in the final multiple model we considered variables with p-value ≤ 0.05.

Organization of the databank was supported with the Tabnet app (http://www2.datasus.gov.br/DATASUS/index.php?area=02) and the IBM program SPSS version 20 (https://www.ibm.com/), in which the databank aggregation was done, with calculation of the indicators and the statistical indicators.

Results

From 2001 to 2017, the under-five mortality rate decreased from 23.39 deaths per 1,000 live births in 2001 to 14.28 deaths per 1,000 live births in 2015, followed by a slight increase in 2017, with 14.41 deaths per 1,000 live births. The study thus found a significant downward trend in the under-five mortality rate and the existence of moderate correlations between this outcome and healthcare factors, sanitation conditions, maternal schooling, and per capita household income.

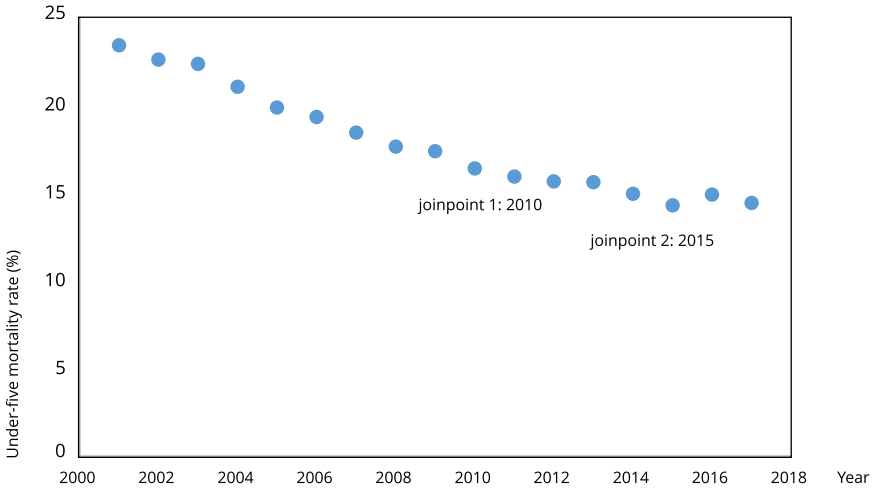
The trend in under-five mortality showed two moments of statistically significant decline (downturn), in 2010 (AAPC = -3.95) and 2015 (AAPC = -2.35), representing mean annual reductions of 3.95% from 2001 to 2010 and of 2.35% from 2011 to 2015 (Figure 1).

The analysis of correlation between under-five mortality rates and socioeconomic factors (income and schooling) and sanitation conditions (sewage disposal and running water) showed a significant correlation (p ≤ 0.05) in both periods (2001 to 2005 and 2011 to 2015). As for healthcare, there was no uniform behavior in the two periods; in the first there was only a correlation with prenatal care (p ≤ 0.05), and in the second there was a correlation with the variables "nurse visit", "doctor's visit", "childcare counseling", and "appointments for children under one year" (p ≤ 0,05) (Table 1).

In the multiple linear regression analysis, the variable "proportion of illiterate women over 15 years of age" was determinant in explaining the reduction in under-five mortality in both periods (p < 0.001), while water supply (p = 0.009) and appointments for children under one year (p = 0.004) were determinant in the first period, and sewage disposal (p < 0.001) in second period (Table 2).

Figure 1

Trend in under-five mortality rates in Intermediate Urban Linkage Regions (RIAU) , Brazil, by joinpoint analysis (2001 to 2017).



Note: joinpoint 1: inflection point of the 1st period from 2001 to 2010; joinpoint 2: inflection point of the 2nd period from 2011 to 2015. Average annual percentage change (AAPC) significantly different from zero to alpha = 0.05 in the periods from 2001 to 2010 (AAPC = -3.95) and from 2011 to 2015 (AAPC = -2.35) and not significant in the period of 2016 and 2017 (AAPC = -0.07), with a 95% confidence interval (95%CI) for all periods.

Table 1

Means, standard deviations (SD), and Pearson's correlations between under-five mortality and socioeconomic and healthcare indicators. Intermediate Urban Linkage Regions (RIAU), Brazil, 2001 to 2015.

Variables	Period 1 (2001 to 2005)				Period 2 (2011 to 2015)			
	Mean	SD	r	p-value	Mean	SD	r	p-value
Under-five mortality rate	22.65	5.52	-	-	16.04	3.35	-	-
Percentage of children in households earning up to 1/4 minimum wage	48.46	23.60	0.649	**< 0.001**	31.48	19.42	0.684	**< 0.001**
Proportion of illiterate women over 15 years of age	0.17	0.09	0.640	**< 0.001**	0.12	0.07	0.584	**< 0.001**
Proportion of households with open-air sewage	0.19	0.15	0.515	**< 0.001**	0.06	0.06	0.534	**< 0.001**
Proportion of households with sewage disposal	0.32	0.29	-0.364	**< 0.001**	0.20	0.15	-0.459	**< 0.001**
Proportion of households with running water supply	0.67	0.17	-0.471	**< 0.001**	0.40	0.11	-0.303	**< 0.001**
Proportion of nurse visits	0.34	0.20	-0.043	0.590	0.14	0.10	0.303	**< 0.001**
Proportion of medical visits	0.24	0.16	-0.061	0.446	0.08	0.05	0.267	**0.001**
Proportion of prenatal care appointments	0.86	0.49	0.156	**0.049**	1.16	0.46	0.147	0.063
Proportion of childcare appointments	1.89	1.66	0.066	0.408	2.22	2.13	0.309	< 0.001
Proportion of appointments for children under 1 year	6.32	3.76	-0.019	0.814	6.95	5.70	0.186	**0.018**
Proportion of appointments for children 1 to 4 years of age	1.27	0.73	-0.066	0.403	1.07	0.79	0.116	0.142

Table 2

Multivariate linear regression between under-five mortality and socioeconomic and healthcare indicators. Intermediate Urban Linkage Regions (RIAU), Brazil, 2001 to 2015.

	r^2	r	Variables kept in model	β	p-value
Period 1 (2001 to 2005)	0.462	0.679	Proportion of illiterate women over 15 years of age	34.747	< 0.001
			Proportion of households with running water	-5.886	0.009
			Medical appointments in children under 1 year	-0.255	0.004
Period 2 (2011 to 2015)	0.401	0.696	Proportion of illiterate women over 15 years of ages	21.883	< 0.001
			Proportion of households with sewage disposal	-5.981	< 0.001

Discussion

The fourth MDG, in which the target was a two-thirds reduction in under-five mortality compared to 1990, was reached successfully by Brazil before the deadline in the international agreement, which was 2015. The target was met through a combination of efforts at the global, national, and local levels, with the results saving millions of children's lives and improving the living conditions of many others. This shows that targeted interventions plus the use of adequate resources, solid strategies, and political determination favors surprising and unprecedented strides even in countries with high poverty rates [3].

During the proposed period, Brazil was one of the 62 countries that met the fourth MDG, with a reduction of 73% in under-five mortality, thus surpassing the two-thirds target [16]. This result calls attention to the fact that infant survival, especially in vulnerable families, continues to escape government control. It also underscores the still-limited global progress, since fewer than one-third of the 191 countries that committed to the MDGs reached the fourth target of decreasing and controlling the under-five mortality rate. Avoidable diseases such as pneumonia, diarrhea, and malaria accounted for approximately 16,000 deaths per day worldwide in children under five years of age in 2015. Thus, the drastic decline in avoidable under-five mortality is one of the most important achievements in human history [3].

In Brazil, the drop under-five mortality occurred in all the country's major geographic regions, notwithstanding regional economic asymmetries. According to data from the Institute of Applied Economic Research (IPEA), from 1990 to 2011 there was a reduction in regional inequality, with a decrease in under-five mortality in all regions of the country, notably the Northeast (a reduction of 76%, or an average of 6.6% per year) [1].

Meanwhile, in 2015, with the economic crisis that struck Brazil, there was a sharp slowdown in the annual reduction of the under-five mortality rate (0.2% per year), compared to the period from 2010 to 2015 (0.8% per year), due mainly to the increase in poverty rates [17]. This calls attention to the possible stabilization of under-five mortality rates, given the results in 2016 and 2017. Recent data showed an increase in deaths from causes such as pertussis, highlighting the importance of maintaining activities in surveillance, immunization, and pediatric care [18].

In 2016, alleging adjustment to the public accounts, the Brazilian Federal Government started adopting a series of fiscal austerity measures, culminating in *Constitutional Amendment n. 95* (EC95), which pegs adjustments on public spending in health to the inflation rate until the year 2036. Forecasts point to an increase in under-five mortality as a consequence of the economic crisis and the subsequent implementation of these fiscal austerity policies [9,17].

The cutback in the health budget has tangible effects on children's health. It is thus indispensable to adopt government measures aimed at health promotion and protection of the population, especially children, through the maintenance of investments in the SUS and in social programs, due to children's greater vulnerability to economic crises.

In the current study, extreme poverty (percentage of children in households earning up to one-fourth the minimum wage), followed by women's lack of schooling (proportion of illiterate women over 15 years of age) were the variables with the strongest correlations with under-five mortality and thus have a major influence on the determination of the proposed final models. Conditional cash transfer programs and programs that increase the value of the minimum wage or distribute social benefits contribute to the reduction of deaths in children by favoring more adequate access to health services and education for families, besides conditioning their retention in the programs [19]. This reinforces the importance of public policies that bolster families' income and promote public education with quality.

Studies have already indicated the potential impact of such programs on poverty, on the families' health and nutritional status, especially that of children, on access to food, and on health services in various Latin American countries, contributing considerably to the reduction in extreme poverty and to the decrease in inequalities and improvement in health levels [20,21]. Since 2015, the percentage of poor Brazilians has increased again, and one of the main contributing factors has been the cutbacks in conditional cash transfer programs like *Bolsa Família* [8]. The latter is a conditional cash transfer program created by the Brazilian Federal Government in 2003, targeted to families in situations of extreme poverty and those considered poor and with children under 17 years, pregnant or breast-feeding women, who receive a monetary stipend based on meeting specific conditionalities, involving health, education, and social assistance issues [22].

Data from the United Nations show that improvements in child survival occurred unequally between families in Brazil and the world. Surveys of family clusters reveal disproportionality in the vulnerability of children in the poorest clusters compared to children in the wealthiest family clusters, such that under-five mortality rates are nearly twice as high in children in the poorest clusters compared to children in the wealthiest [3]. This inequality was found recently in a microsimulation study on the impact of fiscal austerity measures in Brazil, with a resulting reduction in investments in social assistance programs like *Bolsa Família*. Estimates point to an increase in under-five morbidity and mortality and in social inequalities, with the poorest municipalities disproportionately affected [17].

Lack of women's schooling was another indicator that proved to be a strong and consistent predictor of under-five mortality. The significant influence of maternal education on a child's health and survival is thus an important area of research [23]. Maternal education contributes to the mother's awareness of good health practices, in situations of the children's illness and availability of health services, so that it is considered a factor that positively affects the child's health. A study in Sub- Saharan Africa confirmed that children of mothers with more schooling run less risk of dying before the fifth year of life, when compared to children of mothers with no formal education [24]. Despite the observation that schooling favors better work and income, the eradication of illiteracy and investment in education need to be accompanied by opportunities for participation in the labor market in order to allow mothers the sufficient material conditions to care for their children.

Health factors also showed a strong and inverse correlation with the under-five mortality rate. The changes Brazil has experienced in recent years and that culminated in the improvement of some of its socioeconomic and health indicators, decreasing the difficulties in access to and use of the means for the promotion, protection, recovery, and rehabilitation of the population's health, contributed directly to the reduction in under-five mortality [25,26].

It has been known for some time that investments in basis sanitation, namely in the running water supply, sewage disposal, solid waste treatment, storm drainage, and urban cleaning are extremely relevant for public health promotion through the prevention of diseases and improvement in people's quality of life and well-being. Still, public actions in sanitation, implemented in Brazil, are subject to heavy political and economic pressures, resulting in discontinuity, due to the low investments and institutional and legal weaknesses [27].

Recent years have witnessed an increase in the coverage of sanitation services, but universal access to this type of service in Brazil is still a challenge, far from being reached. Various studies have reported this difficulty, emphasizing the difference in access between different regions of Brazil and between income and schooling levels, resulting in the production of a divided society, with different access to fundamental rights such as basic sanitation *(Law n. 11,445)* [28,29].

In 2010, 59.4%, 39.7%, and 58.6% of the Brazilian population received adequate service in running water supply, sewage disposal, and solid waste management, respectively, creating a significant deficit in all the components of basic sanitation, that is, millions of Brazilians living in unhealthy environments subject to various health risks [30]. This context of exclusion and inequality, in some situations accompanied by low quality of the existing services, is the product of a development model based on the capitalist mode of production, which in turn promotes contradictions, antagonism, and iniquities [31].

Basic sanitation programs are known to be a priority, especially in areas with increased vulnerability, since they represent effective support for the improvement of health, as well as for the reduction of mortality in children and in the population as a whole [32]. It is thus crucial to develop public policies that seek to guarantee universal access to sanitation services with a focus on the population's demands, through adequate investments and social participation, not limited to the elaboration of projects or constrained exclusively by neoliberal policies that curtail State action.

Health is the result of interaction between social, environmental, and economic variables that trigger pressures on living conditions and quality of life. The public system's weakness and a deficient sanitation infrastructure directly favor the development of infectious diseases and thus child morbidity and mortality, especially in poor and developing countries [33].

In 2007, the Brazilian government created the Growth Acceleration Program (PAC), leading to a significant expansion of financing for sanitation in the country. The program's design featured a set of legislative and administrative measures and investment policies, aimed at stimulating growth of the country's economy, earmarking resources for priority infrastructure areas (logistics, energy, transportation, housing, and sanitation, among others). However, for actions in sanitation, although the PAC led to the expansion of funding and favored the resumption of investments in the area, it was not sufficient to develop measures and actions to fully meet the guidelines of the Brazilian National Basic Sanitation Law [29]. Since the program aimed to contribute to the country's development, strengthening the national path to economic growth, the PAC adhere closely to an economic and technocratic logic, prioritizing most of the budget resources for sectors that favor capital gain, with sanitation works left in second place.

Alongside contextual determinants, health actions are extremely important in the determination of under-five mortality. In the current study, medical care for infants (under one year of age) showed an influence on the reduction of the under-five mortality rate. Measures that contribute to health services access, providing incentives to increase vaccination coverage and food and nutritional security, expanding coverage by the FHS, and improving living conditions in general avoid many causes of under-five deaths, so that health problems never or rarely evolve to death [34,35].

The implementation of the Community Health Agents program and the FHS in the 1990s allowed the expansion of access to basic healthcare services and valuing family health teams, culminating in an increase in coverage of reproductive and infant healthcare [8]. In 1995, the FHS was present in 115 Brazilian municipalities, but by December 2013 it had reached 95% of Brazil's cities [1]. The Family Health Strategy has improved health outcomes and reduced health inequalities in Brazil. In addition, the consolidation da FHS has contributed to the reduction of the infant, under-five, and maternal mortality rates, with decreases in the rates of vaccine-preventable diseases and hospitalizations for avoidable conditions [24]. A study that evaluated the Family Health Program's impact on infant mortality in Brazil in 1990-2002 showed for every 10% expansion in the coverage of the FHS, there was a 4.6% decrease in infant mortality [36].

The expansion of coverage by primary care, sustained by the FHS, was essential for achieving the current under-five mortality rates, but maintaining the results is directly related to health funding, thus the need to maintain the results and to expand budget resources for the SUS.

Finally, the study showed that indicators related to schooling, sanitation, and healthcare interventions are determinants of under-five mortality and are thus included in the final multiple analysis models.

Final remarks

The analysis of the evolution in under-five mortality showed a significant reduction in most of the period studied (2001 to 2015), with a trend towards stabilization since 2015. This raises a red flag for surveillance of the factors involved in this indicator, especially since Brazil met the fourth target of the MDGs and reached the lowest under-five mortality rates in the country's history. Use of the joinpoint methodology allowed the study to conduct a statistical analysis of the under-five mortality trend, highlighting the moments with the largest turns in the trends, promoting the study of factors involved in the results obtained during that period.

The study found correlations between economic, educational, sanitation, and healthcare factors and improvement in under-five mortality during the periods studied. The multiple regression model also showed the large influence of women's schooling and sanitation, suggesting that these indicators contribute to access and health outcomes.

The challenges in the context of public budget cutbacks highlight the need to strengthen the SUS, due to the importance of the system's health interventions for meeting the targets in under-five mortality proposed by the SDGs.

The study further emphasizes Brazil's performance in surpassing the fourth target of the MDGs and all the difficulties involved in maintaining these results, given Brazil's context of political and economic crisis and the implementation of fiscal austerity measures. This emphasizes the need to maintain policies for the protection of life, along with new public policy proposals that can act on the social determinants of health that impact morbidity and mortality in childhood, guaranteeing the actions' sustainability for the coming years. The results can provide lessons on policies to be followed and paths to be avoided.

Contributors

C. S. R. Marinho participated in the study conceptualization and project, data analysis and interpretation, writing of the article, and critical revision of the relevant intellectual content. T. B. M. Flor and J. M. F. Pinheiro contributed in the data analysis and interpretation, writing of the article, and critical revision of the relevant intellectual content. M. A. F. Ferreira contributed in the critical revision of the relevant intellectual content and approval of the final version for publication.

Additional informations

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Resumo

No ano 2000, foram estabelecidos os Objetivos de Desenvolvimento do Milênio (ODM), que teve como quarta meta a redução da mortalidade na infância (em menores de 5 anos). Desde 2010, o Brasil alcançou a meta proposta. O objetivo deste estudo foi analisar o comportamento da mortalidade na infância e a correlação com os indicadores assistenciais, socioeconômicos e sanitários das regiões brasileiras que contribuíram para o país atingir os ODM. Trata-se de um estudo ecológico, com o uso de dados secundários do Brasil, por Regiões Intermediárias de Articulação Urbana (RIAU), no período de 2001 a 2017. Foram realizadas análises de tendência por meio do joinpoint *e modelos de regressão linear múltipla. Constatou-se uma tendência de redução da taxa de mortalidade em menores de 5 anos nos períodos estudados, com maior inflexão estatisticamente significativa entre os anos de 2001 a 2010 (AAPC = -3,95; IC95%: -4,3; -3,6), com menores valores de 2011 a 2015 (AAPC = -2,35; IC95%: -3,7; -1,0) e estabilização em 2016 e 2017 (AAPC = -0,07; ICC = -4,2; +4,3). A baixa renda (extrema pobreza) das famílias das crianças e a ausência de escolaridade feminina foram as variáveis que mais se correlacionaram com a taxa da mortalidade na infância (r = 0,649, p < 0,001 e r = 0,640, p < 0,001, respectivamente). O cumprimento da quarta meta dos ODM pelo Brasil fez com que o país alcançasse um evidente progresso na redução da taxa de mortalidade na infância, porém percebe-se uma possibilidade de estabilização nesta taxa nos últimos anos. Por outro lado, indicadores sociais e ações assistenciais de saúde foram de grande importância nessa redução, constituindo um desafio ao país a manutenção e evolução das políticas públicas.*

Disparidades nos Níveis de Saúde; Saúde da Criança; Mortalidade

Resumen

En el año 2000 se establecieron los Objetivos de Desarrollo del Milenio (ODM), cuya cuarta meta era la reducción de 2/3 de la mortalidad en la infancia (en menores de 5 años). Desde 2010, Brasil alcanzó la meta propuesta. El objetivo de este estudio fue analizar el comportamiento de la mortalidad en la infancia y la correlación con los indicadores asistenciales, socioeconómicos y sanitarios de las regiones brasileñas que contribuyeron a que país alcanzara los ODM. Se trata de un estudio ecológico, con la utilización de datos secundarios de Brasil, por Regiones Intermediarias de Coordinación Urbana (RIAU en Portugués), durante el período de 2001 a 2017. Se efectuaron análisis de tendencia a través de joinpoint *y modelos de regresión lineal múltiple. Se constató una tendencia de reducción de la tasa de mortalidad en menores de 5 años durante los períodos estudiados, con mayor inflexión estadísticamente significativa durante el periodo de 2001 a 2010 (AAPC = -3,95; IC95%: -4,3; -3,6), con menores valores en 2011 a 2015 (AAPC = -2,35; IC95%: -3,7; -1,0) y estabilización en 2016 y 2017 (AAPC = -0,07; ICC = -4,2; +4,3). La renda baja (extrema pobreza) de las familias de los niños y la ausencia de escolaridad femenina fueron las variables que más se correlacionaron con la tasa de la mortalidad en la infancia (r = 0,649, p < 0,001 y r = 0,640, p < 0,001, respectivamente). El cumplimiento de la cuarta meta de los ODM, por parte de Brasil, consiguió que el país alcanzase un evidente progreso en la reducción de la tasa de mortalidad en la infancia, pese a que se percibe una posibilidad de estabilización en esta tasa en los últimos años. Por otro lado, indicadores sociales y acciones asistenciales de salud se revelaron de gran importancia en esa reducción, al constituirse en un desafío para el país en cuanto al mantenimiento y evolución de las políticas públicas.*

Disparidad en el Estado de Salud; Salud del Niño; Mortalidad

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