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Leading causes of child mortality in Brazil, in 1990 and 2015: estimates from the Global Burden of Disease study

Principais causas da mortalidade na infância no Brasil, em 1990 e 2015: estimativas do estudo de Carga Global de Doença

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ABSTRACT: ***Objective:*** To analyze under-5 mortality rates and leading causes in Brazil and states in 1990 and 2015, using the Global Burden of Disease Study (GBD) 2015 estimates. ***Methods:*** The main sources of data for all-causes under-5 mortality and live births estimates were the mortality information system, surveys, and censuses. Proportions and rates per 1,000 live births (LB) were calculated for total deaths and leading causes. ***Results:*** Estimates of under-5 deaths in Brazil were 191,505 in 1990, and 51,226 in 2015, 90% of which were infant deaths. The rates per 1,000 LB showed a reduction of 67.6% from 1990 to 2015, achieving the proposed target established by the Millennium Development Goals (MDGs). The reduction generally was more than 60% in states, with a faster reduction in the poorest Northeast region. The ratio of the highest and lowest rates in the states decreased from 4.9 in 1990 to 2.3 in 2015, indicating a reduction in socioeconomic regional disparities. Although prematurity showed a 72% reduction, it still remains as the leading cause of death (COD), followed by diarrheal diseases in 1990, and congenital anomalies, birth asphyxia and septicemia neonatal in 2015. ***Conclusion:*** Under-5 mortality has decreased over the past 25 years, with reduction of regional disparities. However, pregnancy and childbirth-related causes remain as major causes of death, together with congenital anomalies. Intersectoral and specific public health policies must be continued to improve living conditions and health care in order to achieve further reduction of under-5 mortality rates in Brazil.

Keywords: Mortality. Cause of death. Vital Statistics. Evaluation.

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RESUMO: ***Objetivo:*** Analisar as taxas de mortalidade e as principais causas de morte na infância no Brasil e estados, entre 1990 e 2015, utilizando estimativas do estudo Carga Global de Doença (*Global Burden of Disease* – GBD) 2015. ***Métodos:*** As fontes de dados foram óbitos e nascimentos estimados com base nos dados do Sistema de Informações sobre Mortalidade (SIM), censos e pesquisas. Foram calculadas proporções e taxas por mil nascidos vivos (NV) para o total de óbitos e as principais causas de morte na infância. ***Resultados:*** O número estimado de óbitos para menores de 5 anos, no Brasil, foi de 191.505, em 1990, e 51.226, em 2015, sendo cerca de 90% mortes infantis. A taxa de mortalidade na infância no Brasil sofreu redução de 67,6%, entre 1990 e 2015, cumprindo a meta estabelecida nos Objetivos de Desenvolvimento do Milênio (ODM). A redução total das taxas foi, em geral, acima de 60% nos estados, sendo maior na região Nordeste. A disparidade entre as regiões foi reduzida, sendo que a razão entre o estado com a maior e a menor taxa diminuiu de 4,9, em 1990, para 2,3, em 2015. A prematuridade, apesar de queda de 72% nas taxas, figurou como a principal causa de óbito em ambos os anos, seguida da doença diarreica, em 1990, e das anomalias congênitas, da asfixia no parto e da sepse neonatal, em 2015. ***Conclusão:*** A queda nas taxas de mortalidade na infância representa um importante ganho no período, com redução de disparidades geográficas. As causas relacionadas ao cuidado em saúde na gestação, no parto e no nascimento figuram como as principais em 2015, em conjunto com as anomalias congênitas. Políticas públicas intersetoriais e de saúde específicas devem ser aprimoradas.

Palavras-chave: Mortalidade. Causas de morte. Estatísticas vitais. Avaliação.

INTRODUCTION

Under-5 mortality rates (or child mortality rates) constitute a key indicator in the assessment of the health status of a population. Its inclusion in the Millenium Development Goals (MDGs) from 1990–2015[1], and in the Sustainable Development Goals (SDGs) for the period until 2030[2], emphasizes its importance. In this sense, the follow-up of child mortality represents an opportunity to develop preventive strategies, addressed to reducing the risk of death in this age group by using public policies related to children's health.

In the past 25 years, Brazil has registered a major reduction in child mortality, reaching its goal number 4 of the MDGs before 2015[3]. However, the current levels are still high[4]; therefore, it is important to assess the performance of this indicator per state to identify regional inequalities. The analysis of the leading causes of death in childhood is particularly relevant to define effective preventive actions.

Most infant deaths occur in the first year of life, mainly during the first month. There is a high percentage of perinatal causes, such as prematurity, which indicates the importance of factors related to pregnancy, delivery, and postpartum, generally avoidable trough qualified health care[5].

The Brazilian Ministry of Health has made specific investments in the national information systems over the past few years. Among the proposals, some can be highlighted: the inclusion of goals related to the quality of information about deaths on the Agreement and

Integrated Program established between the municipal and federal level of government, the systematic implementation of active search of unregistered deaths and the investigation of deaths declared as ill-defined, besides actions addressed to strengthen maternal and child/fetal death committees[6-8]. However, there are still regional differentials regarding the completeness of death registration and the inadequate recording of causes of death[9].

The latest version of the Global Burden of Disease Study – GBD 2015[10] gathered regional estimates for some countries, including Brazil, and represents a unique opportunity for studies addressed to the different regional contexts in the country, using standardized methodology for the correction of problems regarding the quality of available statistics. The objective of this study was to use the estimates of the GBD 2015 study to assess child mortality rates in 1990 and 2015 in Brazilian states, and the leading causes of death, in order to contribute to the establishment of adequate interventions.

METHODS

The sources of data in this study were the estimates of deaths and live births (LB) in the GBD 2015 study[10], coordinated by the Institute for Health Metrics and Evaluation – IHME), at the University of Washington. According to the methodology used, different types of data available for the country and the states – including the Federal District – from 1980 to 2013, were considered in the model to estimate the probability of death for the under-5 age group for 1990 and 2015. Besides deaths registered by the Mortality Information System (SIM), the estimation of under-5 mortality rates considered complete or summary birth histories data from demographic census and household surveys – the National Household Sample Survey – PNAD, and the Demographic and Health Survey (PNDS). Bias correction was conducted by comparison with a defined reference source[10] for each state after consulting with experts in the country.

Under-5 mortality rates estimates were obtained after the conduction of several stages of statistical modeling. First, level of mortality was assessed according to the levels of some covariables, such as education and income. In order to harmonize the series of time according to geographic location, a smooth space-time model was used to reduce the differences between the values predicted in the regression model, and the values observed. A regression model was applied for the final adjustment, using the Gaussian Process Regression – GPR to synthetize all the sources and simultaneous correction of bias from specific sources. The final estimates of under-5 and adult mortality rates, along with HIV/Aids crude death rates, were parameters for the model life table system used in GDB 2013 and 2015, generating deaths estimated by age and sex, with 95% uncertainty intervals for each measure[11]. The Cause of Death Ensemble Modeling (CODEm) was used in the analysis of causes of death. CODEm tests several possible statistical models of causes of deaths and creates a combined set of models

that provides the best predictive performance for estimating specific causes of death[10,12]. All estimates with data sources and 95% uncertainty intervals for Brazil and other countries are available in IHME's website (http://www.healthdata.org/results/data-visualizations), which are annually updated with a standardized methodology for all countries and the entire study period[10].

This study included all deaths estimated for the country in children under 5 years of age, in 1990 and 2015. For analyzing causes of death, the GDB study uses a list to classify causes, first proposed in 1996 and updated in further studies[10], considered more adequate for the formulation and follow-up of health policies[13]. In this list, the causes are organized in level 1 in three major groups: infectious diseases, maternal, perinatal, and nutritional causes (Group I); chronic degenerative diseases (Group II); and external causes (Group III). These groups are subdivided into 21 broader categories (level 2), and in subcategories of specific causes (levels 3 and 4)[10].

The following causes of death were analyzed in this study: prematurity, congenital anomalies, asphyxia and trauma at birth, septicemia and other neonatal infections, lower respiratory tract infections, other neonatal disorders, diarrheal diseases, malnutrition, foreign body aspiration, road injuries, drowning, homicide (interpersonal violence), endocrine, metabolic, blood or immune disorders, cardiomyopathy and myocarditis, syphilis, pertussis, hemolytic disease of the newborn, and neonatal jaundice. The corresponding codes in ICD-10 for each group of cases were previously described[10].

To define the leading causes of child mortality in Brazil and Brazilian states, the sorting of specific mortality rates per cause was considered, after the redistribution of ill-defined and unspecific causes of death (garbage codes), and correction of errors in classification of HIV/AIDS according to the GBD methodology[10]. This methodology recommends that certain codes from the International Classification of Diseases (ICD) should not be considered as an underlying cause of death as they do not characterize this cause sufficiently to enable adequate public health interventions. These codes are named garbage codes, and considering that the burden of disease is estimated according to specific causes, these codes are redistributed[14]. Among more than 4,000 codes in the ICD-10 are considered to be garbage in the GBD 2015 study, the following were registered at a higher proportion in the SIM, in 2015, for children under 5 years of age: J18.0-J18.9-Unspecified pneumonia (n = 1,452), R00-R99-III-defined causes of death (n = 1,120), and A40.0-A41.9-Septicaemias (n = 779).

This study used the number of live births as denominator, representing the probability of death of children under 5 years of age, according to GBD studies[12] but different from the estimates available in the link http://www.healthdata.org/results/data-visualizations, by IHME, which consider the estimated under-5 population in the denominator. The agreement between both rates are high, according to Laurenti & Santos (1996)[15].

RESULTS

The number of under-5 deaths in Brazil presented an important reduction from 191,505 in 1990 to 51,226 in 2015,shown in Figure 1 according to age groups. It is possible to notice a change in the proportions of deaths by age between the periods: in 1990, the highest number of deaths was in the postneonatal period (28-364 days), representing approximately 44% of under-5 deaths, followed by the early neonatal (0–6 days), childhood (1–4 years) and late neonatal (7–27 days). In 2015, early neonatal mortality rates were the main component of child mortality, corresponding to 41% of total deaths, followed by the age groups of 28–364 days, 7–27 days, and 1–4 years old. Therefore, infant deaths represented about 90% of the total number of deaths for under-5 years old in 2015.

Table 1 provides the number of child deaths and the estimated mortality rates in the states and the country, in 1990 and 2015. Rates in Brazil were 52.5/1,000 LB in 1990, and 17.0/1,000 LB in 2015, which represent a 67.7% reduction. In 1990, among the 11 states with the highest under-5 mortality rates, nine were in the Northeast region, all presenting rates higher than 60/1,000 LB. Mortality rates in Alagoas (114.1/1,000 LB) were 4.9 times higher than those in the state which had the lowest mortality rate, Rio Grande do Sul (23.2/1,000 LB); the difference was 91deaths per 1,000 LB. Conversely, in 2015 the ratio between the highest (Acre, 27.0/1,000 LB) and the lowest rates (Rio Grande do Sul, 12.0/1,000 LB) was reduced to 2.3, showing a much smaller difference: 15 deaths per 1,000 LB. In that year, among the 10 states with the highest rates, four were from the Northern region of Brazil.

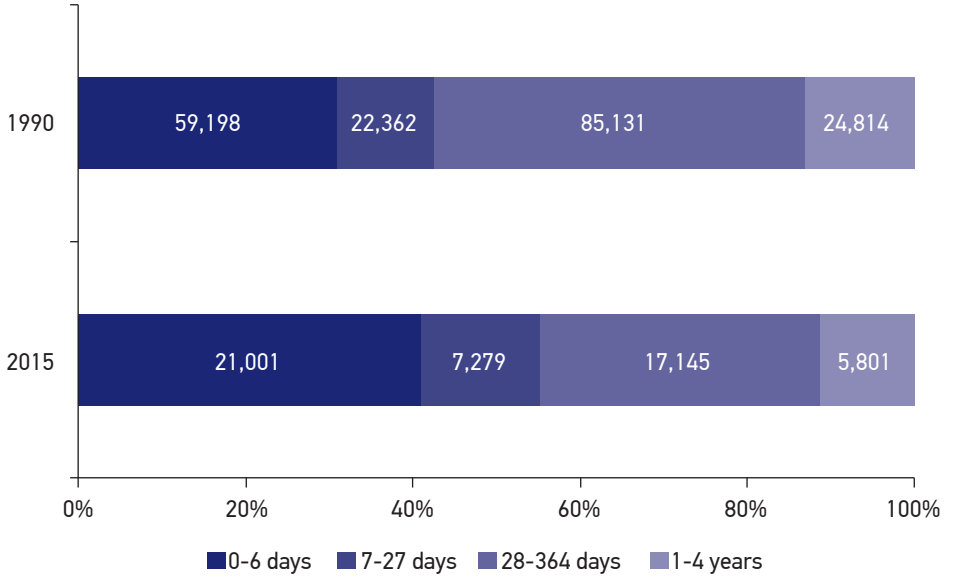

Figure 1. Proportions (%) and number of deaths in under-5 mortality by age group. Brazil, 1990 and 2015.

The average reduction of mortality rates between 1990 and 2015 was 4.41% per year. The total reduction of child mortality rates was, in general, higher than 60%, much higher in the Northeast region than in other Brazilian regions (Table1).

Chart 1 shows the leading causes of death per 1,000 LB for children under 5 years of age in 1990 and 2015. Notably we can observe a reduction of 94.7% on mortality due

Table 1. Under-5 mortality rates per 1,000 live births. Brazil and states, 1990 and 2015.

States	1990		2015		Percentage change (%)
	n	Rate/ 1,000 LB	n	Rate/ 1,000 LB	
Acre	993	67.7	482	27.0	-60.1
Alagoas	8,409	114.1	1,104	18.5	-83.8
Amapá	411	38.0	350	21.4	-43.8
Amazonas	3,581	54.0	1,460	17.5	-67.6
Bahia	24,050	75.2	5,449	23.0	-69.4
Ceará	17,627	95.5	3,068	21.8	-77.2
Distrito Federal	1,057	26.3	606	14.5	-44.7
Espírito Santo	2,551	39.8	816	14.8	-62.8
Goiás	3,332	34.9	1,556	16.5	-52.7
Maranhão	14,222	86.3	3,434	24.2	-71.9
Mato Grosso	2,307	41.8	734	13.8	-67.1
Mato Grosso do Sul	1,497	32.1	639	15.0	-53.3
Minas Gerais	15,146	40.9	4,271	15.3	-62.7
Pará	10,323	63.1	2,941	18.4	-70.9
Paraíba	5,875	68.9	1,069	16.6	-75.9
Paraná	6,529	32.1	2,105	13.8	-56.9
Pernambuco	16,797	88.2	3,065	20.7	-76.5
Piauí	4,726	64.0	1,197	23.0	-64.1
Rio de Janeiro	9,655	37.9	2,995	14.4	-62.0
Rio Grande do Norte	4,907	74.3	790	14.9	-80.0
Rio Grande do Sul	4,580	23.2	1,658	12.0	-48.3
Rondônia	1,573	48.5	428	14.8	-69.5
Roraima	351	58.2	265	25.0	-56.9
Santa Catarina	3,639	33.6	1,392	15.9	-52.8
São Paulo	22,760	33.1	8,055	13.7	-58.5
Sergipe	3,027	70.1	748	20.8	-70.4
Tocantins	1,583	59.2	550	20.3	-65.8
Brazil	191,505	52.5	51,226	17.0	-67.7

LB: Live births.

to diarrhoeal diseases in the period: in 1990, they represented the second top cause in under-5 mortality, decreasing to the seventh position in 2015. Deaths due to lower respiratory infections and malnutrition, with relative ranking in the third and seventh positions shifted over time to the fifth and ninth positions, respectively. Despite this important reduction, eight among the ten leading causes of death in the country in 2015 still correspond to Group I (maternal, neonatal, nutritional and infectious diseases). In contrast, some causes did not follow this trend and showed only a mild decrease, such as intrapartum asphyxia (rate = 1.93/1,000 LB) and neonatal sepsis (rate = 1.69/1,000 LB), which led to its rise in the relative ranking, from fourth to third, and from sixth to fourth position, respectively.

Prematurity was the top cause of death in both years, despite the remarkable 72.0% decrease in its rates: 11.35/1,000 LB in 1990, and 3.18/1,000 LB in 2015. Congenital anomalies were in the fifth position in 1990, and became the second leading cause in 2015, despite the lower reduction in rates in the period – from 3.31 to 3.06/1,000 LB. Some external causes also appear in the first 20 positions in 2015, despite the decrease trend of its rates: foreign body aspiration held the 10th position, road injuries 11th, drowning 12th, and interpersonal violence 13th. Of note is the reduction in rates due to syphilis and vaccine preventable diseases, such as pertussis and measles.

Table 2 and Figure 2 present the leading causes of child deaths in Brazilian states in 2015. The two main causes were prematurity and congenital anomalies. Congenital anomalies were the leading cause of death in the states of the South, Center-west, and Southeast regions – except for Minas Gerais and Goiás. In most states in the North and Northeast regions, the leading cause of death was prematurity. Asphyxia appears as the third or fourth cause of death in most states; however, in Maranhão it is the second leading cause of death.

It is important to mention that in all states of the North and Northeast regions, including Mato Grosso, Mato Grosso do Sul and Espírito Santo states, malnutrition is still among the under-5 ten leading causes of mortality in 2015, but with low mortality rates. Rates ranged from 0.1/1,000 LB (São Paulo) to 0.9/1,000 LB (Roraima).

DISCUSSION

The findings show an important under-5 mortality reduction in all states in 2015 compared to 1990. This trend indicates the homogenization of child mortality rates in the country, with expressive decrease in mortality differentials among states over time. The reduction of mortality was more expressive in the states of the Northeast region, which presented the highest levels in 1990.

With regard to the causes of death, communicable, maternal, neonatal, and nutritional conditions were still the leading causes in 2015, and they, generally, can be considered avoidable[16]. A positive change has occurred for diarrheal diseases, which

Chart 1. Leading causes of under-5 deaths for both sexes combined. Brazil, 1990 and 2015.

1990				2015				Change % (rates)
Ranking	Cause of death	n	Rate per 1,000 LB	Ranking	Cause of death	n	Rate per 1,000 LB	
1	Prematurity	41,385	11.35	1	Prematurity	9,588	3.18	-72
2	Diarrhoeal diseases	40,370	11.07	2	Congenital anomalies	9,242	3.06	-7
3	Lower respiratory infections	29,779	8.17	3	Asphyxia and trauma at birth	5,834	1.93	-49
4	Asphyxia and trauma at birth	13,784	3.78	4	Septicaemia and other neonatal infections	5,112	1.69	-34
5	Congenital anomalies	12,061	3.31	5	Lower respiratory infections	4,677	1.55	-81
6	Septicemia and other neonatal infections	9,421	2.58	6	Other neonatal disorders	4,405	1.46	36
7	Malnutrition	8,565	2.35	7	Diarrhoeal diseases	1,761	0.58	-95
8	Meningitis	5,348	1.47	8	Meningitis	945	0.31	-79
9	Other neonatal disorders	3,916	1.07	9	Malnutrition	938	0.31	-87
10	Road injuries	2,379	0.65	10	Foreign body aspiration	806	0.27	-34
11	Syphilis	1,930	0.53	11	Road injuries	734	0.24	-63
12	Pertussis	1,793	0.49	12	Drowning	417	0.14	-61
13	Foreign body aspiration	1,478	0.41	13	Homicide	401	0.13	-40
14	Drowning	1,283	0.35	14	Endocrine, metabolic, blood and immune disorders	396	0.13	18
15	Hemolytic diseases and other neonatal	1,026	0.28	15	Cardiomyopathy and myocarditis	371	0.12	-50
16	Fire, heat and hot substances	992	0.27	16	HIV/Aids	368	0.12	29
17	Measles	950	0.26	17	Leukemia	322	0.11	-18
18	Cerebrovascular diseases	933	0.26	18	Other cardiovascular and circulatory diseases	307	0.10	-56
19	Cardiomyopathy and myocarditis	889	0.24	19	Sudden infant death syndrome	258	0.09	53
20	Other cardiovascular and circulatory diseases	835	0.23	20	Other neoplasms	235	0.08	-39
21	Homicide	803	0.22	25	Cerebrovascular diseases	211	0.07	-73
25	Leukemia	473	0.13	26	Syphilis	208	0.07	-87
26	Other neoplasms	469	0.13	27	Hemolytic diseases and other neonatal	199	0.07	-77
34	Endocrine, metabolic, blood and immune disorders	406	0.11	30	Fire, heat and hot substances	170	0.06	-79
36	HIV/Aids	345	0.09	40	Pertussis	80	0.03	-95
43	Sudden infant death syndrome	204	0.06	74	Measles	3	0.00	-100

Table 2. Mortality rates per 1,000 live births and number of deaths (in parentheses), according to leading causes in Brazilian states in 2015.

State	Prematurity	Congenital Anomalies	Asphyxia	Septicaemia	Lower respiratory infections	Other neonatal disorders	Diarrhoeal diseases
Acre	5.4 (97)	3.6 (64)	3.2 (57)	2.5 (44)	3.5 (62)	1.5 (26)	1.7 (30)
Alagoas	3.8 (225)	2.9 (173)	2.1 (123)	1.9 (115)	1.7 (104)	1.1 (65)	1.2 (73)
Amapá	3.8 (62)	3.1 (51)	2.8 (46)	2.9 (48)	2.4 (40)	1.3 (21)	0.8 (13)
Amazonas	2.9 (242)	3.1 (256)	1.9 (162)	1.5 (123)	2.1 (174)	1.2 (103)	1.0 (85)
Bahia	4.7 (1.118)	3.3 (775)	2.8 (654)	2.1 (497)	2.0 (476)	2.0 (479)	1.0 (236)
Ceará	4.5 (632)	3.1 (444)	2.5 (348)	2.6 (371)	1.9 (269)	1.6 (233)	0.9 (125)
Distrito Federal	2.8 (117)	3.3 (137)	1.6 (66)	1.2 (50)	1.1 (45)	1.3 (55)	0.3 (13)
Espírito Santo	2.1 (118)	3.0 (165)	1.7 (95)	1.1 (60)	1.1 (63)	1.6 (89)	0.5 (26)
Goiás	3.2 (298)	3.2 (297)	1.8 (165)	1.8 (167)	1.6 (150)	1.2 (117)	0.4 (34)
Maranhão	4.2 (596)	3.2 (459)	3.5 (496)	2.0 (287)	2.7 (379)	2.1 (297)	1.3 (190)
Mato Grosso	2.4 (125)	2.8 (148)	1.3 (70)	1.4 (73)	1.3 (69)	1.1 (59)	0.4 (23)
Mato Grosso do Sul	2.4 (102)	3.0 (129)	1.7 (71)	1.4 (58)	1.4 (61)	1.2 (51)	0.7 (28)
Minas Gerais	3.3 (922)	2.9 (823)	1.6 (450)	1.7 (463)	1.1 (320)	1.3 (351)	0.3 (81)
Pará	3.4 (543)	2.9 (469)	2.2 (350)	2.2 (351)	2.3 (367)	1.2 (186)	0.7 (111)
Paraíba	2.7 (171)	3.1 (197)	1.5 (96)	1.8 (119)	2.1 (133)	0.9 (57)	0.9 (56)
Paraná	2.3 (356)	3.1 (471)	1.5 (232)	0.9 (143)	1.0 (145)	1.5 (230)	0.3 (45)
Pernambuco	3.1 (459)	3.2 (480)	2.3 (342)	1.9 (287)	2.0 (300)	2.3 (339)	1.4 (211)
Piauí	4.0 (206)	3.3 (170)	2.8 (147)	1.7 (91)	2.0 (104)	3.1 (161)	1.2 (60)
Rio de Janeiro	2.4 (506)	2.9 (605)	1.7 (347)	1.5 (313)	1.2 (252)	1.6 (327)	0.2 (40)
Rio Grande do Norte	2.9 (154)	2.8 (151)	1.7 (88)	1.6 (83)	1.4 (76)	1.1 (56)	0.5 (27)
Rio Grande do Sul	2.0 (281)	3.1 (421)	1.2 (166)	1.2 (162)	1.0 (132)	1.0 (132)	0.2 (27)
Rondônia	2.4 (70)	2.9 (85)	1.6 (45)	1.5 (42)	1.5 (43)	0.9 (27)	0.7 (19)
Roraima	4.6 (49)	3.7 (40)	2.6 (28)	2.0 (21)	3.4 (36)	2.3 (25)	1.3 (13)
Santa Catarina	2.8 (242)	3.2 (283)	1.6 (139)	1.6 (141)	1.3 (116)	1.1 (100)	0.4 (34)
São Paulo	2.8 (1.670)	3.0 (1.757)	1.5 (877)	1.5 (901)	1.1 (627)	1.2 (692)	0.2 (98)
Sergipe	3.7 (134)	3.1 (110)	2.8 (102)	1.5 (53)	2.2 (79)	2.0 (71)	1.1 (39)
Tocantins	3.4 (93)	3.1 (83)	2.7 (72)	1.8 (49)	2.1 (57)	2.0 (54)	0.8 (23)

Causes of death	Brasil	North							Northeast									Southeast				South			Center-West			
		Rondônia	Acre	Amazonas	Roraima	Pará	Amapá	Tocantins	Maranhão	Piauí	Ceará	Rio Grande do Norte	Paraíba	Pernambuco	Alagoas	Sergipe	Bahia	Minas Gerais	Espírito Santo	Rio de Janeiro	São Paulo	Paraná	Santa Catarina	Rio Grande do Sul	Mato Grosso do Sul	Mato Grosso	Goiás	Distrito Federal
Prematurity	1	2	1	2	1	1	1	1	1	1	1	1	2	2	1	1	1	1	2	2	2	2	2	2	2	2	1	2
Congenital anomalies	2	1	2	1	2	2	2	2	3	2	2	2	1	1	2	2	2	2	1	1	1	1	1	1	1	1	2	1
Asphyxia and trauma at birth	3	3	4	4	4	5	4	3	2	4	4	3	5	3	3	3	3	4	3	3	4	3	4	3	3	4	4	3
Septicaemia	4	5	5	5	6	4	3	6	6	6	3	4	4	6	4	6	4	3	6	5	3	6	3	4	5	3	3	5
Lower respiratory infection	5	4	3	3	3	3	5	4	4	5	5	5	3	5	5	4	6	6	5	6	6	5	5	6	4	5	5	6
Other neonatal disorders	6	6	7	6	5	6	6	5	5	3	6	6	6	4	7	5	5	5	4	4	5	4	6	5	6	6	6	4
Diarrheal diseases	7	7	6	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	10	9	8	7	9	7	7	8	8
Meningitis	8	10	9	9	10	9	10	10	9	10	8	9	9	9	10	9	9	8	9	8	8	9	9	10	10	11	7	9
Malnutrition	9	9	8	8	8	8	8	8	8	8	10	8	8	8	8	8	8	11	8	11	14	11	12	12	8	9	11	11
Foreign body aspiration	10	11	13	13	17	12	15	11	11	13	12	11	13	10	15	11	10	9	11	7	7	7	10	8	9	8	10	7
Road injuries	11	8	10	11	9	10	12	9	10	9	9	10	10	11	9	10	11	10	10	12	10	10	8	11	11	10	9	10
Drowning	12	12	11	10	12	11	11	12	12	11	11	16	17	19	14	15	12	14	13	17	18	14	15	16	14	12	15	20
Homicide	13	13	12	14	13	13	13	15	16	18	13	15	12	12	11	13	13	17	12	13	15	16	23	18	13	14	12	12
Endocrine, metabolic, blood, and immune disorders	14	14	14	17	11	16	14	13	18	14	17	14	15	14	13	14	14	12	14	14	13	13	14	13	12	13	14	14
Cardiomyopathy and myocarditis	15	16	22	19	14	19	20	16	15	15	15	19	11	17	16	17	16	13	18	15	12	18	17	20	16	18	13	13
HIV/AIDS	16	18	34	12	16	15	18	28	21	27	28	28	24	18	19	29	30	19	15	9	11	17	13	7	15	16	17	19
Leukemia	17	20	17	15	25	18	22	18	20	16	14	13	16	22	17	18	18	15	17	18	16	15	16	15	17	19	16	15
Other cardiovascular and circulatory diseases	18	23	20	23	20	17	19	21	17	19	16	21	18	20	18	22	15	16	20	16	17	20	18	17	21	21	23	27
Sudden infant death syndrome	19	19	25	34	15	29	9	17	30	21	19	33	31	15	30	16	32	18	29	31	20	12	11	14	20	17	22	17
Other neoplasms	20	22	33	20	23	20	16	27	26	23	22	18	21	23	20	24	25	21	21	21	19	19	21	19	19	23	18	16

Figure 2. Regional rankings for under-5 leading causes of death by states. Brazil, 2015.

in 1990 were the second leading cause of death, and in 2015 moved to the seventh position, with expressive rate reduction. This change indicates improvements in sanitation and nutritional conditions in the country[17-19], as well as access to health care, besides the possible impact of specific actions, such as the introduction of a vaccine against rotavirus in 2006[20], and oral rehydration therapy in primary care[21]. Respiratory conditions, and particularly whooping cough had similar results. The impact on the reduction of mortality rates due to Group I diseases can also be attributed to the National Immunization Program (PNI), with increasing vaccine coverage, and introduction of the MMR vaccine (measles, rubella and mumps vaccine) and the pneumococcal vaccine[22].

In contrast, congenital anomalies had relatively stable rates in Brazil in the period, and are currently the leading cause of death in almost half of the states, especially those presenting lower mortality rates, coming close to the epidemiological profile found in high-income countries[10].

It should be noted that the expressive participation of external causes – accidents and violence – among the 15 top causes of death of under 5 mortality, especially among the subgroup of children 1 to 4 years of age , has become a major health problem for families and society. Despite the important reduction in rates in the period analyzed, it was identified that 2,358 children deaths were due to of foreign body aspiration, road injuries, drowning, and homicide, that is, 1 out 20 under 5 children died from these causes in the country. There are also cases of violence against children, usually domestic violence, indicating that social violence also affects childhood[23].

With regard to the percentage of the annual decline of mortality rates from all causes, the GBD 2015 study compares the performance of the Brazilian states in relation to countries with a similar socioeconomic level, measured by the SDI (socio-demographic index)[24]. The most important reductions in mortality rates are found in the North and Northeast regions, and lower decreases are found in the South and Southeast. As a result, mortality rates in some states, such as Ceará, Rio Grande do Norte, Paraíba, Pernambuco, and Sergipe are not as high as expected, considering the group of countries with similar socioeconomic conditions. This is possibly related to the effectiveness of specific interventions in these areas[25,26], thus reducing the regional differences, resulting in decrease in socioeconomic inequities[27].

The United Nations (UN) 2013 report pointed out the role of a combination of national strategies that were essential for reducing child mortality rates in Brazil, especially the Unified Health System (SUS), with several improved actions in the past decade, such as the improvement of the maternal and newborn care, social care policies, like the income transfer program *Bolsa Família*[28], besides a series of improvements in life conditions and for the health care of children. The creation of the Family Health Program increased the access to primary health care in the poorest cities, and had a positive impact on the reduction of infant mortality[29]. Both the reduction in the prevalence of malnutrition and the increased rates of breastfeeding contributed to the decreasing rates of child mortality in the period[4].

The fact that most deaths occurred in the first month of life shows the importance of factors related to pregnancy, birth, and the postpartum period for the reduction of infant mortality rates to a level that is compatible with the economic development of the country. The strengthening of the perinatal care network, with continuous care, from prenatal until neonatal, is a strategy that is being constantly reorganized in the country[30-32].

Brazil has made progress in its prenatal care coverage, and the current challenge is to qualify care in order to promote pregnant women's health and the fetus, ensuring proper diagnosis and interventions to prevent prematurity and infections during pregnancy[30,33-34]. Worrisome factors are the increasing incidence rates of congenital syphilis – from 2.0/1,000 LB in 2006 to 6.5/1,000 LB in 2015[35] – which is related to the quality of prenatal care, and the appearance of the Zika virus infection[36].

Qualifying labor and birth care, when most deaths occur[37], is an essential strategy. The challenge of reducing iatrogenic prematurity and intra-partum asphyxia, which are the result of improper termination of pregnancy and other interventions during labor and birth should be taken into consideration as these actions are still common in Brazil and are associated with neonatal mortality[5,38,39]. Studies highlight the increasing prematurity rates associated with high rates of cesarean sections in Brazil[30]. Policies encouraging natural labor are essential for reducing prematurity, seeking improvements in survival and in the quality of life during childhood[40]. Deaths caused by intrapartum asphyxia, in turn, could be reduced by 36% in countries similar to Brazil with access to childbirth health care[41].

The progress in access and quality of care provided to the newborn at risk, requiring intensive and specialized care, especially premature newborns, should also be the focus of public policies. The training of hospital professionals caring for newborns, in neonatal reanimation, is an effective strategy for reducing neonatal mortality[33]. The quality of perinatal hospital care needs to be monitored by process indicators, besides perinatal results. The monitoring networks of neonatal care have shown discrepant results among perinatal services in cases where the technology is similar, especially regarding premature newborns[42].

Some limitations should be considered regarding the results in this study. Besides the occurrence of garbage codes, even in 2015, indicating the need to improve physician certificates in terms of causes of child mortality, the important under-recording of deaths at SIM, especially in the North and Northeast regions in 1990, led to the constant use of correction models, with several limitations that were previously discussed[10]. Besides, the non-availability of SIM data from 2014 and 2015 as a source of reference data in the modeling of the GBD 2015 study increases the uncertainty of estimates for those years. Recent empirical data indicate a lower completeness estimated by the GBD study for some states compared with results of other Brazilian analyses[43].

Such inaccuracies, however, do not affect the main results and the major contribution of the GBD approach in terms of improving the knowledge about mortality risks. The strength of this analysis is to demonstrate the consistent reduction of child mortality rates, the presence of avoidable causes of death still relevant in the country, and the possibility of making

regional comparisons and with those of other countries by using remarkable tools to visualize the GBD study results.

CONCLUSION

The results of this study, based on the estimates of the GBD 2015 study, confirm the consistent reduction in child mortality rates in the country. The rates in the period, despite having decreased, are still high in 2015, including preventable causes related to pregnancy, labor and birth health care are among the leading causes of death. Specific intersectoral and health public policies should be put into practice and improved to increase the reduction of child mortality rates in Brazil.

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