Original article

Mortality on the first day of life: trends, causes of death and avoidability in eight Brazilian Federative Units, between 2010 and 2015*

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Abstract

Objective: to calculate mortality rates on the first day of life from 2010 to 2015 in eight Brazilian Federative Units providing better quality information, to assess associated factors and to classify deaths by underlying causes and avoidability. **Methods:** this was a descriptive study; mortality rates were compared according to maternal and child characteristics; avoidability analysis used the 'Brazilian list of avoidable causes of death'. **Results:** 21.6% (n=20,791) of all infant deaths occurred on the first day of life; the mortality rate reduced from 2.7 to 2.3 deaths/1,000 live births; rates were higher in live births with low birthweight and preterm births, and among babies born to mothers with no schooling; main causes of death were respiratory distress syndrome (8.9%) and extreme immaturity (5.2%); 66.3% of causes of death were avoidable. **Conclusion:** 2/3 of deaths on the first day of life could have been avoided with adequate care for women during pregnancy and delivery and adequate care for live births.

Keywords: Infant Mortality; Causes of Death; Child Health; Information Systems; Vital Statistics.

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Introduction

The infant mortality rate has declined sharply in the last three decades in most regions of the world.[1,2] However, in the same period, the reduction in neonatal mortality (deaths between zero and 27 days of life) has been slow, especially in early neonatal mortality (deaths between zero and six days of life). This reduction has occurred unevenly across countries according to their level of development.[2] Between 1990 and 2012, the neonatal mortality rate decreased by 65% in East Asia, while in sub-Saharan Africa and Oceania, it decreased by only 28% and 17%, respectively.[3] The causes of neonatal death vary according to the level of the infant mortality rate. In countries with higher mortality rates, half of neonatal deaths are caused by infections, whereas in countries with lower rates, prematurity and congenital malformations are the major causes of death.[1]

> *In Brazil, approximately a quarter of infant deaths happen on the first day of life.*

In Brazil, the decrease observed in infant mortality in recent decades has been accompanied by a slow reduction in neonatal mortality and an increase in preterm births.[4-6] Currently, infant mortality is mainly comprised of early neonatal mortality.[7] The 'Born in Brazil' survey, a national hospital database study of puerperal women and their newborn babies, conducted between 2011 and 2012, identified a neonatal mortality rate of 11.1 deaths/1,000 live births (LB), with the highest rates being found in the country's North and Northeast regions. Prematurity and low birth weight were the main characteristics associated with neonatal deaths in Brazil.[8]

The day on which birth occurs, as well as being biologically relevant, is the most risky day for survival. Although substantial progress has been made in other areas of child health, the neonatal period, particularly the first day of life, has been relatively neglected in many regions of the world. Risk of death in this most vulnerable period of life is 30 times higher in low-income countries, in comparison to high-income countries.[9] Deaths on the first day of life account for 25 to 45% of deaths in the neonatal period.[10] In Brazil, approximately a quarter of infant deaths happen on the first day of life.[7] These deaths can be the target of interventions and their prevention consists of access to high-quality care in the prenatal period, during delivery and immediately after birth.[1]

Epidemiological studies on mortality in the first day of life are necessary to understand the preventability of these deaths and to improve early neonatal mortality indicators in Brazil. The main objectives of this study were to calculate mortality rates on the first day of life from 2010 to 2015 in eight Brazilian Federation Units providing best quality information, to analyze associated factors and to describe causes of death according to underlying cause and avoidability.

Methods

This was a descriptive study, using secondary data from the Mortality Information System (SIM) and the Live Birth Information System (SINASC) provided by the Brazilian Ministry of Health through the Brazilian National Health System Information Technology Department (DATASUS) and accessed in 2017.

The data retrieved corresponds to infant deaths occurring between 2010 and 2015 in seven Brazilian states (Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul) and the Federal District. This vital information is considered to be adequate according to Inter-Agency Health Information System (RIPSA) criteria, and the infant mortality rate can be calculated without the need to correct data provided by SIM and SINASC, owing to the method used for active tracing of deaths and births.[11] The period selected for analysis can be justified by the fact that Death Certificate and Live Birth Certifcate forms underwent a process of change between 2007 and 2009. With effect from 2010, progress with data coverage and quality of data can be seen, especially regarding causes of death.[12] The data were therefore selected with the aim of presenting the best quality available information on deaths and births occurring in Brazil.

Underlying causes of death on the first day of life were described according to the International Statistical Classification of Diseases and Related Health Problems (ICD - 10th Edition (ICD-10). For the analysis of death preventability we used the 'Brazilian list of causes of avoidable deaths by SUS interventions in children under five years old.'[13] As

the frequency of underlying causes of death did not vary between 2010 and 2015, the analyses of causes of death and preventability were presented for the total of deaths occurring in the period considered. Analysis of preventability of deaths according to birth weight categories was also performed.

The variables relating to live births (LB) and childbirth were:

- Sex (male; female);
- Ethnicity/skin color (white; black; Asian; brown; indigenous)
- Multiple pregnancy (yes; no);
- Type of delivery (vaginal, cesarean section);
- Birth weight (in grams: <1,500; 1,500-2,499; ≥ 2,500);
- Gestational age in weeks: pre-term, <37; term, 37-41; post-term ≥42).

The variables relating to the mother were:

- Age (in years: <20; 20-29; ≥30);
- Education level (in years of completed study: no schooling; 1-3; 4-7; 8-11; ≥12 years).

We calculated the mortality rates for the first day of life (number of deaths occurring on the first day of life, by 1,000 LB, by place and year) and the proportion of deaths on the first day of life in relation to deaths of under one-year-olds in the period between 2010 and 2015, for the eight Federative Units (FUs) selected. Percentage variation of mortality rates on the first day of life for each FU over the period was calculated in the following way:

$$\frac{[\text{final mortality rate} - \text{initial mortality rate}]}{\text{initial mortality rate}) \times 100}$$

Time trend analyses were performed using linear regression, after verification of non-correlation between the standard errors over time, using Breusch Godfrey's chi-squared test. In the simple linear regression analysis, mortality rates were considered to be a dependent variable and the year was considered to be an independent variable.

Mortality rates for the first day of life were compared in relative terms (relative risk, RR) and absolute terms (attributable risk, AR, absolute difference between rates), according to the characteristics of live births, childbirths and the mothers of the newborn in the period studied. Association between these characteristics and death on the first day of life was verified by means of statistical tests based on Pearson's chi-squared test.

The project was carried out in accordance with the ethical principles defined in National Health Council (CNS) Resolution No. 466 dated 12 December 2012.

Results

Between 2010 and 2015, there were 96,170 infant deaths in the eight Federal Units selected. The infant mortality rate reduced by 13% in the period, falling from 12.7 deaths/1,000 LB to 11.0 deaths/1,000 LB ($p<0.001$). Of the total number of infant deaths, 20,791 (21.6%) occurred on the first day of life. Considering the total study period, the mortality rate on the first day of life was of 2.5/1,000 LB, varying between 2.7 deaths/1,000 LB in 2010 and 2.3 deaths/1,000 LB in 2015 ($p=0.009$) (Table 1).

Between 2010 and 2015, while Mato Grosso do Sul state and the Federal District had the highest mortality rates on the first day of life (both with 3.4 deaths per 1,000 LB), Rio Grande do Sul reported the lowest rate (2.3/1,000 LB). With the exception of Santa Catarina state, the other states analyzed showed a reduction in the death rate on the first day of life over the period, in particular the state of Paraná ($p=0.016$) and the state of Mato Grosso do Sul ($p=0.002$), where the mortality rates on the first day of life reduced by 29% and 28%, respectively (Table 2).

Live births with greatest risk of dying on the first day of life were those of the male sex, indigenous ethnicity/skin color, multiple pregnancies, vaginal birth, birth weight <1,500g, infants born preterm, children of adolescent mothers and children of mothers with no schooling (Table 3).

Standing out among the 20 major causes of death on the first day of life, was neonatal respiratory distress syndrome (8.9%), followed by extreme immaturity (gestational age <28 weeks) (5.2%) and very low birth weight (<1,000g) (5.2%) (Table 4).

The majority of causes of death on the first day of life (66.3%) were considered to be avoidable causes. 40.8% of these deaths could have been avoided through adequate care of the pregnant woman, 13.3% through adequate care of the fetus and the newborn baby, 12.1% through adequate care of women during childbirth and 0.1% through appropriate diagnosis, treatment and health promotion actions. 33.5% of deaths did

Table 1 – Number, proportion and rate of infant deaths on the first day of life, in eight selected Brazilian Federative Units[a] 2010-2015

Indicator	2010	2011	2012	2013	2014	2015	2010-2015
Number of deaths in children younger than 1 year old	16,188	16,233	16,110	15,855	16,119	15,665	96,170
Number of LB[b]	1,322,755	1,347,588	1,359,709	1,362,801	1,401,060	1,424,720	8,218,633
Infant mortality rate/1,000 LB[b]	12.7	12.0	11.8	11.6	11.5	11.0	11.7
Number of deaths on the 1st day of life	3,600	3,579	3,385	3,386	3,558	3,283	20,791
Proportion (%) of deaths on 1st day of life	22.2	22.0	21.0	21.4	22.0	20.9	21.6
Mortality rate on the 1st day of life/1,000 LB[b]	2.7	2.6	2.5	2.5	2.5	2.3	2.5

a) Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul and the Federal District.
b) LB: live births.
Sources: Brazilian Live Birth Information System (SINASC), 2010-2015; Mortality Information System (SIM), 2010-2015.

Table 2 – Mortality rates on the first day of life, in eight selected Brazilian Federative Units, 2010-2015

Federative Unit	Mortality rate on the first day of life/1,000 LB[a]								
	2010	2011	2012	2013	2014	2015	2010-2015	Mudança no período [b]	Valor de p[c]
Espírito Santo	3.0	2.7	2.6	2.4	2.7	2.7	2.7	-9%	0.349
Rio de Janeiro	2.9	2.9	2.5	2.5	2.7	2.3	2.6	-23%	0.059
São Paulo	2.5	2.4	2.4	2.4	2.4	2.2	2.4	-12%	0.048
Paraná	3.1	2.8	2.7	2.6	2.7	2.2	2.7	-29%	0.016
Santa Catarina	2.4	3.0	2.5	2.6	2.7	2.5	2.6	5%	0.888
Rio Grande do Sul	2.4	2.5	2.1	2.2	2.3	2.1	2.3	-10%	0.158
Mato Grosso do Sul	4.1	3.7	3.4	3.2	3.1	3.0	3.4	-28%	0.002
Federal District	3.7	3.1	3.2	3.2	3.7	3.4	3.4	-6%	0.909

a) LB: live births.
b) Percentage change in the mortality rate on the first day of life, between 2010 and 2015.
c) P-value for linear trend - Wald test.
Sources: Brazilian Live Birth Information System (SINASC), 2010-2015; Mortality Information System (SIM), 2010-2015.

not have clear avoidable causes and ill-defined causes of death corresponded to 0.2% of the total number of causes of death on the first day of life. The Federal District had the highest percentage of causes of deaths reducible by adequate care of pregnant women (51.8%) and a lower frequency of deaths reducible by adequate care of women during child delivery (8.5%). Santa Catarina and São Paulo states had the highest frequency of deaths reducible by adequate care of the fetus and newborn baby (16.4% and 16.1%, respectively). Regarding the top 20 causes of death, 14 were preventable causes: nine were attributed to other causes reducible by adequate care of pregnant women; three were causes reducible by adequate care of the fetus and the newborn baby; and two were causes reducible by adequate care of women during childbirth. The other six were not clearly preventable causes (Table 4).

Analysis of avoidable causes by categories of birth weight showed that in those weighing less than 1,500g, most deaths were reducible by adequate care for pregnant women (56.3%), while in the 1,500-2,499g and ≥2,500g weight ranges, the category of other not clearly avoidable causes was predominant (61.0% and 44.2%, respectively). It is possible that about one in four deaths with birthweight ≥2,500g (26.3%) could have been reduced by adequate care for women during childbirth (Table 5).

Discussion

In our study, one fifth of all infant deaths occurred on the first day of life. The majority of FUs selected for the study showed a reduction in the rate of deaths on the first day of life in the period between 2010 and 2015. Mortality rates on the first day of life were

Table 3 – Number and rate of deaths on the first day of life, according to live birth, delivery and mothers' characteristics, in eight selected Federative Units,[a] 2010-2015

Characteristics of LB[b] and delivery	2010-2015					
	n[c]	LB[b]	Rate[d]	Relative risk	p[e]	Attributable risk
Sex	20,637				<0.001	
Male	11,454	4,209,135	2.7	1.18 (1.15;1.22)		0.4
Female	9,183	4,008,464	2.3	1.00		(reference)
Ethnicity/skin color	19,310				<0.001	
Black	531	392,374	1.4	0.50 (0.46;0.55)		-1.3
Asian	34	29,189	1.2	0.43 (0.31;0.60)		-1.5
Brown	4,984	2,508,899	2.0	0.74 (0.71;0.76)		-0.7
Indigenous	108	28,919	3.7	1.40 (1.15;1.68)		1.1
White	13,653	5,095,435	2.7	1.00		(reference)
Multiple Pregnancy	19,957				<0.001	
Yes	2,516	184,850	13.6	6.26 (6.00;6.53)		11.4
No	17,441	8,027,587	2.2	1.00		(reference)
Type of delivery	19,886				<0.001	
Cesarean section	8,361	4,985,021	1.7	0.46 (0.45;0.48)		-1.9
Vaginal delivery	11,525	3,226,968	3.6	1.00		(reference)
Birth weight (in grams)	19,775				<0.001	
<1,500	12,579	115,110	109.3	227.50 (219.32;235.99)		108.8
1,500-2,499	3,603	620,557	5.8	12.08 (11.54;12.65)		5.3
≥2,500	3,593	7,480,349	0.5	1.00		(reference)
Gestational age (in weeks)	19,237				<0.001	
<37	15,743	865,195	18.2	37.87 (36.50;39.30)		17.7
37-41	3,416	7,110,518	0.5	1.00		(reference)
≥42	78	151,969	0.5	1.06 (0.85;1.33)		0.0
Mother's age (in years)	19,298				<0.001	
<19	4,310	1,318,618	3.3	1.47 (1.41;1.52)		1.1
≥30	6,006	2,858,240	2.1	0.94 (0.91;0.97)		-0.1
20-29	8,982	4,041,617	2.2	1.00		(reference)
Maternal education level (in years of schooling)[f]	18,014					
No schooling	591	21,616	23.7	17.10 (15.66;18.67)		25.7
1-3	753	188,274	4.0	2.50 (2.30;2.71)		2.4
4-7	4,398	1,506,753	2.9	1.82 (1.74;1.91)		1.3
8-11	9,520	4,710,602	2.0	1.26 (1.21;1.32)		0.4
≥12	2,752	1,720,840	1.6	1.00		(reference)
Total	20,791	8,218,633	2.5			

a) Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul and Federal District.
b) LB: live births.
c) Number of deaths on the first day of life.
d) Mortality rate on the first day of life, calculated in each category of the analyzed variables: number of deaths in the numerator divided by the number of LB x 1,000.
e) P-value - Pearson's chi-squared test.
f) Variable with the highest percentage of missing information (13.4%).
Sources: Brazilian Live Birth Information System (SINASC), 2010-2015; Mortality Information System (SIM), 2010-2015.

Table 4 – 20 main causes of deaths on the first day of life according to ICD-10 classification[a], in eight selected Brazilian Federative Units,[b] 2010-2015

Position	ICD-10 code[a]	Name of the cause of death	N (% of the total number of deaths on the first day of life)	Preventable causes[c]
1	P22.0	Respiratory distress syndrome of newborn	1,856 (8.9)	1
2	P07.2	Extreme immaturity of newborn	1,087 (5.2)	1
3	P07.0	Extremely low birth weight newborn	1,074 (5.2)	1
4	Q00.0	Anencephaly	819 (3.9)	4
5	P01.1	Fetus and newborn affected by premature rupture of membranes	757 (3.6)	1
6	P21.9	Asphyxia at birth, unspecified	754 (3.6)	2
7	P02.1	Fetus and newborn affected by other forms of placental separation and hemorrhage	742 (3.6)	4
8	P28.0	Primary atelectasis of newborn	615 (3.0)	3
9	Q89.7	Multiple congenital malformations, not classified elsewhere	606 (2.9)	4
10	Q33.6	Congenital hypoplasia and dysplasia of lung	541 (2.6)	4
11	P00.1	Fetus and newborn affected by maternal renal and urinary tract diseases	471 (2.3)	1
12	P02.7	Fetus and newborn affected by chorioamnionitis	458 (2.2)	4
13	P07.3	Preterm (premature) newborn (other)	452 (2.2)	1
14	P00.0	Fetus and newborn affected by maternal hypertensive disorders	446 (2.1)	1
15	P01.5	Fetus and newborn affected by multiple pregnancy	437 (2.1)	1
16	P20.9	Intrauterine hypoxia, unspecified	435 (2.1)	2
17	P36.9	Bacterial sepsis of newborn, unspecified	430 (2.1)	3
18	P01.0	Fetus and newborn affected by incompetent cervix	406 (1.9)	1
19	Q89.9	Congenital malformations, unspecified	396 (1.9)	4
20	P96.9	Condition originating in the perinatal period, unspecified	368 (1.8)	3

a) CID-10: International Statistical Classification of Diseases and Related Health Problems– 10th edition.
b) Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul and Federal District.
c) List of causes of avoidable deaths in children under five years old:[13]
1= Reducible by adequate care for pregnant women.
2= Reducible by adequate care for women during childbirth.
3= Reducible by adequate care for the newborn.
4= Other causes (not clearly preventable).
Source: Mortality Information System (SIM), 2010 -2015.

Table 5 – Classification of underlying causes of death on the first day of life according to Brazilian list of avoidable causes of death,[a] by birth weight categories, in eight selected Brazilian Federative Units,[b] 2010-2015

Preventability	Birth weight (in grams)		
	<1,500 %	1,500-2,499 %	≥2,500 %
Reducible by adequate care for pregnant women	56.3	17.6	12.0
Reducible by adequate care for women during childbirth	8.8	8.2	26.3
Reducible by adequate care for the fetus and newborn	12.1	12.9	16.5
Reducible by appropriate health promotion actions, together with appropriate health care actions	–	0.1	0.3
Reducible by adequate diagnosis and treatment	–	–	–
Other causes (Not clearly avoidable)	22.7	61.0	44.2
Underlying causes of death	0.1	0.1	0.7

a) List of causes of avoidable deaths in children under five years old.[13]
b) Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul and Federal District.

higher for live births among babies of the male sex, of indigenous ethnicity/skin color, from multiple pregnancies, with birth weight below 1,500 g, born preterm, babies of adolescent mothers and babies of women with no schooling. The majority of causes of death on the first day of life were considered avoidable. The three major causes of death were respiratory distress syndrome, extreme immaturity and very low birthweight. These are considered to be causes that can be avoided when adequate care is provided to pregnant women.

The downward trend in infant mortality observed in this study highlights Brazil's commitment to achieving the fourth Millennium Development Goal of reducing infant mortality. Brazil achieved half the target set (15.7 deaths per 1,000 LB) before the 2015 deadline.[14] In the period from 2000 to 2010, the infant mortality rate in the country fell from 26.6 to 16.2 deaths per 1,000 LB; the country's Northeast and North regions had the highest rates of infant mortality reduction (5.9% and 4.2% per year, respectively), contributing to reducing the amplitude of the differences in mortality between the major regions of the country.[11] Different circumstances and interventions conducted within the framework of the public sector have contributed to the progress in child survival observed in Brazil in recent decades. These include: (i) the universalization of medical assistance provided by the Brazilian National Health System, with a decrease in the inequalities in access to and coverage of SUS; (ii) socioeconomic and demographic changes; (iii) conditional cash transfer programs; (iv) improvements in sanitation conditions; (v) breastfeeding and immunization promotion programs; and (vi) the implementation of many national and state programs to improve infant health and nutrition.[5,6]

In Brazil as a whole, neonatal mortality has been the form of infant mortality showing the lowest reduction. Similarly, in recent decades an increase in the proportion of early neonatal mortality has been observed.[6,7] In 2015, 70% of infant deaths occurred in the neonatal period and 54% of these deaths occurred in the first seven days of life.[5] The 'Born in Brazil' survey revealed that the highest neonatal mortality rates related to the North and Northeast regions, while the lowest rates were observed in the South, Southeast and Midwest regions.[8] The challenge of reducing neonatal mortality remains, especially early neonatal mortality, and this requires a specific approach to regional inequalities.

The mortality rate on the first day of life shows slight regional variation within the country. Analysis carried out by the Ministry of Health on information for the period 2000 to 2010, showed an increasing trend in these deaths in Northeast region (from 23% in 2004 to 28% in 2010) and a reducing trend in the Southeast region (from 27% in 2000 to 24% in 2010).[15] The downward trend observed in the Southeast was confirmed in the period we analyzed in our study, with the largest reduction in the mortality rate being found in the state of Rio de Janeiro. In our study, the mortality rate on the first day of life was 2.5/1,000 LB. This is lower than the average rate for Latin America and the Caribbean (3.2/1,000 LB in 2010) and higher than the rate found in high-income countries (1.6/1,000 LB in 2013).[9]

We found a higher rate of death on the first day of life in preterm LB infants with birth weight <1,500g. This finding corroborates evidence from a study conducted in the southern region of the municipality of São Paulo in 2001, which reported risk of death on the first day of life five times higher in infants with birth weight <1,000g than among infants weighing 1,000g to 1,499g, and that approximately 40% of extreme preterm babies died before completing one day of life.[16]

In the FUs included in our study, 18.2% of deaths on the first day of life occurred in LB weighing ≥2,500g and in 17.8% of babies born at full term. These figures are similar to those reported by the Brazilian Ministry of Health for the year 2010.[15] While in poor countries, the most frequent causes of mortality in full term LB within the first seven days of life are obstetric infections, trauma and asphyxia, in middle- and high-income countries the main causes of mortality are sudden infant death syndrome and congenital malformations, including congenital heart defects.[17,18] In LB with greater Viability – this being a concept related to greater probability of existence outside the uterus, not limited to a few hours but potentially possible for months and even years,[19] mortality rates are associated with poor access to health care, which complicates the implementation of timely interventions in the period pre- and post-natal.[8]

The mortality rate on the first day of life was higher among boys, infants from multiple pregnancies and those of indigenous ethnicity/skin color. Other studies conducted in different Brazilian regions also found a higher risk of death on the first day of life and in

the neonatal period among boys.[15,20] This finding can be explained by greater frequency of congenital anomalies, low Apgar score at 5 minutes of life, greater need for mechanical ventilation and respiratory distress syndrome in boys when compared to girls.[21] The greater risk of death in infants from multiple pregnancies, compared to infants of single pregnancies, as well as higher rates of preterm births and low birth weight, and a higher number of complications in pregnancy and childbirth, has also been reported in previous studies.[22,23] Our study found higher mortality rates on the first day of life among indigenous children. This finding is in keeping with reports found in previous studies, according to which higher early and late neonatal mortality rates were found in LB with this ethnicity/skin color for Brazil as a whole. The higher rates found among indigenous peoples are probably related to poorer living conditions and problems in accessing prenatal and childbirth care, in comparison to non-indigenous populations in Brazil.[24]

We found that the rate of death on the first day of life was higher among infants delivered via the vagina born to adolescent mothers and women with no schooling. Other studies have demonstrated the protective effect of cesarean sections against neonatal death in infants with extremely low birth weight,[16] increased survival of premature infants born at 22 to 24 weeks,[25] and reduced the probability of low Apgar scores at 5 minutes of life in live births from multiple pregnancies with planned cesarean delivery *versus* vaginal delivery.[26] However, the high rate of cesarean sections evidenced in Brazil is responsible for the epidemic of preterm births, in particular late preterm newborn babies, which implies an excessive number of children at greater risk of morbidity and death in the short term and a greater risk of development problems in the long term.[27] Greater risk of neonatal death in children born to adolescent mothers and mothers with low schooling has been reported in other studies.[28]

The main underlying causes of death on the first day of life found in our study were respiratory distress syndrome, extreme immaturity and very low birth weight, associated with or resulting from prematurity. In the 'Born in Brazil' survey, prematurity accounted for about one third of cases of neonatal deaths, followed by congenital malformations (23%) and infections (19%).[8] Research conducted in the municipality of São Luís, capital of the state of Maranhão, on all neonatal deaths between 2012 and 2014, found that the most frequent causes of death were respiratory causes (32.3%), sepsis (24.4%) and congenital malformations (8.0%).[29] The frequency of specific causes of neonatal death varies between contexts with different rates of infant mortality; therefore the findings of our research coincide with the profile of causes of neonatal death reported in countries with neonatal mortality rates lower than 15/1,000 LB, where the major causes of neonatal deaths are prematurity, asphyxia at birth and congenital causes.[3]

There was a high proportion of deaths on the first day of life that could have been prevented through (i) adequate care for pregnant women during the prenatal period and child delivery, and (ii) appropriate care for the fetus and newborn baby, indicating a need to improve the care offered to both mothers and babies. A study that analyzed data from health surveys in nine Latin American/Caribbean, African and Asian countries reported that four or more prenatal care sessions decreased by approximately 30% the chances of death on the first day of life (adjusted OR=0.71 95%CI 0.52; 0.98).[30]

In our study, analysis of preventability according to birth weight categories found a high proportion of deaths in the ≥2,500g weight range that could have been avoided by adequate care for women during childbirth. In Brazil, failure to use good practices immediately prior to labor, during labor and delivery increases the risk of babies dying.[8] Adequate care for women during childbirth and adequate care for the fetus and the newborn baby is necessary to mitigate the difficulties related to the transition to extra uterine life, facilitating cardiorespiratory adaptation, achieving clinical stability and reducing the mortality rate on the first day of life.[3,30]

Some limitations of this study should be highlighted. Results from secondary data retrieved from health information systems are subject to the limitations of the quality of the information held on the records available. However, we believe that this weakness was mitigated by opting to use the records of FUs having the best and most complete data on infant deaths in Brazil. In this descriptive study, we did not pair the data with live birth information system data. As a consequence, our bivariate analyses could not be controlled for potential confounding factors. We also did not investigate cases of deaths, and therefore there may have been inaccuracies related to the coding of underlying causes of death. The absence of variables

related to the place of occurrence of birth and death prevented analysis of access to and quality of services provided. Finally, our study only included FUs that have good quality information. For this reason, our results cannot be extrapolated for Brazil as a whole.

Mortality rates on the first day of life were higher among live births whose mother's had unfavorable characteristics and among babies born with low birth weight, preterm infants and children of mothers with no schooling. The main underlying causes of death were infant respiratory distress syndrome, extreme immaturity and very low birth weight. These are considered to avoidable through adequate care for pregnant women and newborn babies, suggesting problems in health service access, coverage and/or quality of care provided. Analysis of the preventability of deaths due to specific causes is an important resource for assessing the effectiveness of maternal and child health services, as well provideing estimates that assist in decision-making and planning of public policies. We believe that quality prenatal care and adequate care at birth and for the newborn can avoid most deaths on the first day of life.

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Authors' contributions

Matijasevich A, Maranhão AGK, Teixeira JAM and Araujo WRM participated in the conception and design of the study, analysis and interpretation of the results, writing and critical review of the manuscript. Cortez-Escalante JJ and Rezende LFM contributed to data analysis and interpretation, writing and critical review of the manuscript. All the authors have approved the final version and declared themselves to be responsible for all aspects of the study, ensuring its accuracy and integrity.

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