ORIGINALES

Neonatal mortality trends by region in Brazil, 2015-2019: an ecological study

Tendência de mortalidade neonatal por regiões do Brasil, 2015-2019: um estudo ecológico

Tendencias de mortalidad neonatal por regiones de Brasil, 2015-2019: un estudio ecológico

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ABSTRACT:
Aim: To analyze the trend of neonatal mortality in Brazil from 2015 to 2019 and its preventable causes.
Methods: Ecological time-series study with data extracted from the Mortality Information System and Live Births Information System. Neonatal mortality rates were calculated overall and according to preventable causes. Trend analysis was performed by Prais-Winsten regression.
Results: The overall neonatal mortality rate reduced from 8.78 in 2015 to 8.60 in 2019. Disparities in neonatal mortality rates were observed among regions, with higher rates in the northern (10.3/1,000)

and northeastern (9.9/1,000) regions. The causes preventable by adequate care for pregnancy, delivery and neonatal care prevailed, together totaling 97.8% of neonatal deaths in the period. There was a decreasing trend in preventable causes due to adequate care of the newborn (p < 0.001).
Conclusion: There was a decrease in the neonatal mortality rate in Brazil from 2015 to 2019.

Keywords: Neonatal Mortality; Mortality Registries; Ecological Studies; Time Series Studies.

RESUMO:
Objetivo: Analisar a tendência de mortalidade neonatal no Brasil de 2015 a 2019 e suas causas evitáveis.
Métodos: Estudo ecológico de série temporal com dados extraídos do Sistema de Informação sobre Mortalidade e Sistema de Informações sobre Nascidos Vivos. Foram calculadas as taxas de mortalidade neonatais geral e segundo causas evitáveis. A análise da tendência foi feita pela regressão de *Prais-Winsten*.
Resultados: A taxa de mortalidade neonatal geral reduziu de 8,78 em 2015 para 8,60 em 2019. Foram observadas disparidades nas taxas de mortalidade neonatais entre as regiões, com maiores taxas nas regiões norte (10,3/1.000) e nordeste (9,9/1.000). As causas evitáveis por adequada atenção da gestação, parto e cuidado ao neonato prevaleceram, totalizando juntas 97,8% dos óbitos neonatais no período. Houve tendência decrescente nas causas evitáveis por adequada atenção ao recém-nascido (p < 0,001).
Conclusão: Houve decréscimo na taxa de mortalidade neonatal no Brasil, de 2015 a 2019.

Palavras-chave: Mortalidade Neonatal; Registros de Mortalidade; Estudos Ecológicos; Estudos de Séries Temporais.

RESUMEN:
Objetivo: Analizar la tendencia de la mortalidad neonatal en Brasil de 2015 a 2019 y sus causas prevenibles.
Métodos: Estudio ecológico de series temporales con datos extraídos del Sistema de Información sobre Mortalidad y del Sistema de Información sobre Nacidos Vivos. Se calcularon las tasas de mortalidad neonatal general y por causas evitables. El análisis de tendencias se realizó mediante regresión de *Prais-Winsten*.
Resultados: La tasa global de mortalidad neonatal se redujo de 8,78 en 2015 a 8,60 en 2019. Se observaron disparidades en las tasas de mortalidad neonatal entre regiones, con tasas más elevadas en las regiones septentrional (10,3/1.000) y nororiental (9,9/1.000). Predominaron las causas prevenibles mediante una atención adecuada al embarazo, el parto y los cuidados del recién nacido, que en conjunto sumaron el 97,8% de las muertes neonatales del periodo. Se observó una tendencia a la disminución de las causas prevenibles gracias a los cuidados adecuados del recién nacido (p < 0,001).
Conclusión: Hubo una disminución en la tasa de mortalidad neonatal en Brasil de 2015 a 2019.

Palabras clave: Mortalidad neonatal; Registros de mortalidad; Estudios ecológicos; Estudios de series temporales.

INTRODUCTION

Neonatal mortality is understood as deaths that occur between 0 and 27 days, subdivided into two categories: early neonatal deaths (0 to 6 days of life) and late neonatal deaths[1-3]. The Neonatal Mortality Rate (NMR) is considered one of the most appropriate indicators to measure the quality of life, socioeconomic development, the level of social well-being of a population, as well as its access to health services in a given territory, therefore linked to the intersection of a set of biological, socioeconomic, and healthcare factors that may be directly involved with this phenomenon[4,5].

According to the World Health Organization (WHO), the NMR is an indicator that sensitively assesses the availability, use, and effectiveness of health care, especially the ones provided during the pregnancy-puerperal cycle, to the newborn and the child

up to the first year of life, being a powerful instrument in the context of health situation analyzes to direct public policies in the maternal and child context[6].

In this context, Kropiwiec, Franco, and Amaral[7] claim that NMR is considerably lower in nations with a high Human Development Index (HDI). While countries with low HDI tend to have higher NMRs, showing that these mortality rates are linked to whether to factors related to human development and the conformation of health services that most often have a reduced standard of effectiveness due to the development conditions of a given territory.

Global estimates indicate there was a drastic reduction in the mortality of children under five years of age worldwide, with four million fewer deaths in 2015 compared to the year 2000[8]. Therefore, it was possible to note that the NMR also suffered a considerable decrease in recent decades, jumping from 37 to 18 deaths per thousand live births (LB) in the interstice of 1990-2018 [9].

Regarding neonatal mortality, data from the World Health Organization (WHO) point to discrepancies in the NMR taking into account the distribution between developed, developing, and underdeveloped countries in the period from 1990 to 2019. The data reveal that in this period NMR of Canada, the US, the UK, and Japan were 3.4/1000 LB, 3.6/1000 LB, 2.6/1000 LB, and 0.9/1000 LB, respectively. While in Brazil, Bolivia, Guatemala, and Panama, the NMR was 8.5/1,000 LB, 14.9/1,000 LB; 12.7/1,000 NV, and 8.8/1,000 NV, respectively. On the other hand, countries like Pakistan and the Central African Republic presented NMR of 43.0/1,000 LB and NV; of 41.8/1,000 NV, respectively[10].

Specifically in Brazil, data reveal a reduction in NMR from 25.33/1,000 LB in 1990 to 8.5/1,000 LB in 2019. This reduction scenario is the result of intense institutional work by the Department of Health (DH) in recent decades with the implementation of major programs and agreements such as the Prenatal and Birth Humanization Program (PHPN), the Baby-Friendly Hospital Initiative (IHAC), the National Pact for the Reduction of Maternal and Neonatal Mortality and, more recently, in 2011 the Rede Cegonha Program, designed for the country to reach the 4th goal of the then Millennium Development Goals (MDGs), which was to reduce the infant mortality rate to two-thirds of the rate observed in 1990, a fact that achieved in the same year [10,11].

Despite notable advances in the reduction of neonatal mortality in Brazil over the years, it is salutary to highlight the existing discrepancies in NMR between the regions of the country, where the North and Northeast regions historically concentrate the highest rates concerning the other regions as a result of the social inequalities and iniquity in health that were historically constructed in the country, with the social determinants of health as the background of this context[12-15]. In addition, neonatal deaths, and especially preventable ones, are responsible for a portion of the deaths of children under five years, a fact that brings up the need to seek to analyze the health situation of each region, so that actions can be taken in a targeted manner to extinguish these preventable deaths.

In this way, knowing the NMR trend is necessary since Brazil is a signatory of the Sustainable Development Goals (SDGs) of the United Nations (UN), which foresees the eradication of neonatal mortality from preventable causes and reaching an NMR of 12 deaths per 1,000 LB by 2030 and understanding the phenomena involved with

NMR over time can contribute to the analysis and direction of public policies related to the theme based on scientific evidence[16,17]. In addition, time series studies(15) can show atypical patterns in the evolution of morbidity and mortality rates of diseases and or conditions and the formation of their causes, a factor that allows assessing the impacts produced by targeted actions in a given context, in the present case on the possible modifiable determinants of neonatal mortality.

Thus, this study aims to analyze the trend of neonatal mortality in Brazil from 2015 to 2019 and its preventable causes.

MATERIAL AND METHOD

It's an ecological time-series study to assess the trend in the neonatal mortality rate in Brazil from 2015 to 2019. Ecological studies are relevant for analyzing the health situation of a community, having as a unit of study a particular geographic area. For Antunes and Cardoso[18], time series studies can be defined as a series of quantitative data related to specific moments which are studied according to their temporal distribution. These studies serve to monitor the health of populations, assess the risk of exposure of subjects to a certain injury, predict the occurrence of situations/events in health, provide elements for possible explanations of cause and effect, guide the analysis of the health situation to the development of actions, as well as evaluating the impacts generated by these interventions.

The data refer to neonatal deaths that occurred in Brazil from 2015 to 2019 and were extracted from the Mortality Information System (SIM) and the Live Births Information System (SINASC) through the Department of Informatics of the Unified Health System (DATASUS), public domain online platform of the Department of Health.

Analyzes of overall neonatal mortality rates and preventable deaths were performed. For the classification analysis of the avoidability of neonatal deaths, the Brazilian list of causes of death preventable by actions of the Unified Health System (UHS) was adopted. According to the list, avoidable causes are distributed in the following groups: 1) Reducible by immunoprevention actions; 2) Reducible by adequate care for women during pregnancy; 3) Reducible by adequate care during childbirth; 4) Reducible by adequate care for the newborn; 5) Reducible by appropriate diagnostic and treatment actions; 6) Reduced by adequate health promotion actions. Deaths from ill-defined causes and those from causes that were not preventable were excluded from the analysis[19,20].

Data were extracted and organized in Excel spreadsheets. To calculate the NMR, the quotient between the number of deaths from 0 to 27 complete days, by place of residence, and the number of live births of resident mothers, multiplied by 1,000, was calculated. Neonatal mortality rates were calculated in the period and each year in Brazil and the geographic regions of the Brazilian Institute of Geography and Statistics (BIGS), as well as according to preventable causes in Brazil in the total of 5 years and every year.

To carry out the analysis of trends the *Prais-Winsten* linear regression method was used, which corrects the serial autocorrelation that usually occurs with population data, such as time series in epidemiology. To perform the screen regression method, the

NMR was transformed into a logarithmic scale, to reduce the heterogeneity of the variance of the residues from the analysis of the time series[18]. P = 0.05 was adopted as a critical value in determining the significance of the trend.

The regression results were interpreted and classified as follows: increasing linear trend when the p-value was less than 0.05 and the angular coefficient (beta) *b1* was positive; decreasing linear trend when the value of p was less than 0.05 and the angular coefficient (beta) b1 was negative; stationary linear trend when the p-value was greater than 0.05. Data were processed using the *R software* version 4.0.0.

Because it is an ecological study and, therefore, without subjects, but population aggregates for analysis, it was not necessary to be evaluated by an ethics committee for research with human beings. Furthermore, the data is in the public domain and does not contain information about the identity of the participants or other sensitive information that could violate the secrecy of the data. Therefore, the precepts of Resolution No. 510 of 12/04/2016 of the National Health Council/Ministry of Health of Brazil were complied with.

RESULTS

During the period from 2015 to 2019, 181,231 infant deaths were recorded in Brazil, of which 70% (126,882) were neonatal. Almost 75.0% of neonatal deaths occurred from preventable causes. From 2015 to 2019, there was a reduction in preventable neonatal deaths by 1.2% (Table 1).

Table 1- Distribution of infant and neonatal deaths by year of death. Brasil, 2015 a 2019.

Ano	Infant Deaths	Neonatal Deaths		
		Total	Avoidable	% Avoidable
2015	37.501	26.500	19782	74,6
2016	36.350	25.130	18752	74,6
2017	36.223	25.608	19132	74,7
2018	35.864	25.140	18676	74,3
2019	35.293	24.504	17995	73,4
Total	181.231	126.882	94.337	74,4

Source: Elaborated by the authors based on data from the Mortality Information System (MIS), 2022.

The average death rate in the period was 8.69 deaths per thousand live births. In general, there was a decrease in the neonatal mortality rate in Brazil, from 8.7/1,000 in 2015 to 8.6/1,000 live births in 2019, corresponding to a decrease of 0.18% (Table 2).

There was a decline in neonatal mortality rates in the Northeast region, from 10.1 deaths per thousand live births in 2015 to 9.6 in 2019, and in the Center-West region where the mortality rate reduced from 8.72 deaths to 8. 25 for every thousand live births in the same period. On the other hand, the North, Southeast, and South regions maintained stationary mortality rates between the years 2015 to 2019 (Table 2).

Table 2- Distribution of neonatal mortality rate and trend per 1,000 live births between regions, Brazil, 2015 to 2019.

Brazil/Regions	NMR (2015-2019)	NMR 2015	NMR 2016	NMR 2017	NMR 2018	NMR 2019	b Value	Linear trend p-value	Trend
Brazil	8,69	8,78	8,79	8,76	8,54	8,60	-0,003	0,040	Decrescent
North Region	10,3	10,3	10,4	10,4	10,4	9,9	-0,004	0,126	Stationary
Northeast Region	9,9	10,1	10,2	10,1	9,6	9,6	-0,010	0,020	Decrescent
Southeast Region	7,91	7,87	7,95	7,96	7,73	8,02	-0,000	0,897	Stationary
South Region	7,27	7,47	7,00	7,28	7,23	7,36	-0,000	0,971	Stationary
Midwest Region	8,49	8,72	8,84	8,32	8,35	8,25	-0,010	0,001	Decrescent

Source: Elaborated by the authors based on data extracted from the Information System on Mortality and the Information System on Live Births (ISM, ISLB/DH), 2022.

As for deaths due to preventable causes, there was a predominance of those that can be reduced by actions in the context of care for women during pregnancy (49.0%), followed by deaths that can be avoided by appropriate actions in care for newborns (30, 7%). All preventable causes decreased between 2015 and 2019, with emphasis on those reducible through diagnostic actions and adequate treatment, which decreased by 26.7% (Table 3).

Table 3- Distribution of neonatal deaths according to preventable causes in Brazil. Brazil, 2015-2019.

	2015		2016		2017		2018		2019		Total	
Avoidable Causes	N	%	N	%	N	%	N	%	N	%	N	%
Reducible by:												
Immunization	4	0,0	4	0,0	6	0,0	0	0,0	4	0,0	18	0,1
Care for women during pregnancy	9423	47,6	9021	48,1	9368	49,0	9394	50,3	9010	50,1	46216	49,0
Adequate care for women in childbirth	3629	18,3	3382	18,0	3535	18,5	3397	18,2	3159	17,6	17102	18,1
Adequate care for the newborn	6284	31,8	5921	31,6	5821	30,4	5520	29,6	5462	30,4	29008	30,7
Appropriate diagnosis and treatment actions	161	0,8	147	0,8	143	0,7	114	0,6	118	0,7	683	0,7
Promotion actions linked to attention actions	281	1,4	277	1,5	259	1,4	251	1,3	242	1,3	1310	1,4
Total	19782	100,0	18752	100,0	19132	100,0	18676	100,0	17995	100,0	94337	100,0

Source: Elaborated by the authors based on data extracted from the Information System on Mortality and the Information System on Live Births (ISM, ISLB/DH), 2022.

Deaths that could be prevented by actions related to newborn care, adequate diagnosis and treatment, and promotion actions linked to care actions showed a decreasing trend in the studied period (p<0.05) (Table 4).

Table 4- Time trend of neonatal mortality rate (per 1,000 live births) according to preventable causes in Brazil. Brazil, 2015-2019.

Avoidable Causes	2015 %	2016 %	2017 %	2018 %	2019 %	B Value	Linear trend P	Trend
Reducible by:								
Immunization	0,02	0,02	0,02	0	0,02	0,004	0,194	Stationary
Care for women during pregnancy	35,6	35,9	36,6	37,4	36,8	-0,001	0,795	Stationary
Appropriate care for women in childbirth	13,7	13,5	13,8	13,5	12,9	-0,009	0,087	Stationary
Appropriate care for the newborn	23,7	23,6	22,7	22	22,3	-0,015	<0,001	Decrescent
Appropriate diagnosis and treatment actions	0,6	0,6	0,6	0,5	0,5	-0,038	0,014	Decrescent
Promotion actions linked to attention actions	1,1	1,1	1,0	1,0	1,0	-0,187	0,003	Decrescent

Source: Elaborated by the authors based on data from the Mortality Information System (MIS), 2022.

DISCUSSION

Infant mortality (IM), which includes neonatal deaths, is considered one of the best indicators to measure the quality of life, health, and state of social well-being of a population, and presents an undesirable phenomenon in public health, since they are premature deaths and which in most countries happens due to preventable causes [21].

The present study reveals that there was a decrease in the neonatal mortality rate from preventable causes in Brazil during the period studied. Specifically, the Northeast and Midwest regions were responsible for a reduction of approximately 1.2% in preventable neonatal mortality in the country. On the other hand, the North, Southeast, and South regions maintained stable rates, a fact that needs to be thoroughly analyzed, since what was expected was an NMR with a decreasing trend in all regions. However, this scenery reveals that Brazil has been reaching values well below expectations, as recommended by the goal established by the Sustainable Development Goals (SDGs), which hopes to reduce, by the year 2030, the neonatal mortality rate to less than 12 deaths per thousand live births all over the world [16,17].

Several public policies have been implemented in recent years to reduce neonatal mortality in Brazil, such as the expansion of the Family Health Strategies (FHS), the Stork Network Program, the Bolsa Familia Program, which were fundamental to impact the health of mothers and children through access to income, education, and health services. The actions provided within the scope of these policies have contributed to women and society as a whole achieving a greater level of knowledge about their sexual and reproductive rights, in addition to a restructuring of maternal and child healthcare services. [22-24].

The downward trend in NMR in the country is supported by other studies that have been analyzing this historical series over the last few years, although high neonatal mortality rates are still evident when compared to other countries[15,25,26]. In addition, the present study shows that neonatal deaths represent about 70% of all infant deaths in the period, and of these, almost 75% occurred due to preventable causes, that is, which could have been avoided by qualified maternal-infant care, especially those focused on prenatal care, care in the delivery room and care for newborns in neonatal units[27].

In this context, it is crucial to highlight the fundamental role of the infant and fetal mortality investigation committees in reducing this specific component of IM, which are preventable neonatal deaths, since this phenomenon is the main object of work of these committees, which act directly in the investigation of these deaths, to clarify the failures that culminated in the same, and to propose interventions from the perspective of preventability[28].

As for the analysis of the TMN in the period between the regions of the country, the study shows a higher rate in the north (10.3/1,000) and northeast (9.9/1,000), even surpassing the national TMN in the period (8.69 /1,000), a finding confirmed by other studies that evaluated the time series of neonatal deaths in the country[15,25,26]. These findings confirm the existing discrepancies between the regions of Brazil, as a result of socioeconomic inequalities and difficulties in accessing health services, which are still very pronounced in the north and north regions, despite the incentives for mitigating this problem in recent years[27,29].

Despite the other regions showing lower rates, including concerning the national TMN, the analysis showed that the south and southeast regions have a stationary trend when they should have shown decreasing trends since the implementation of public policies for the reduction of these rates is being fully operated in these regions[25,27].

Regarding neonatal deaths according to preventable causes, although all causes have shown a reduction in the analyzed period, causes preventable by adequate care during pregnancy prevail (49.0%) over the other elements and showed a stationary trend. These findings are corroborated by other studies on the subject, though, in a study analyzing the historical series until 2017, taking into account a period of 10 years, an increasing trend was found according to the preventable cause in question[15,25,26].

The auspicious start and provision of adequate prenatal care are the main factors for reducing maternal and perinatal morbidity and mortality rates since during pregnancy it is possible to identify risk factors that can lead to unfavorable obstetric outcomes, thus carry out adequate prevention and or treatment to mitigate such outcomes[13,27,30].

A nationwide study[31] that evaluated the quality of prenatal care in the Family Health Strategies (FHS) showed low adequacy of infrastructure, care, and management for the operation of prenatal care in the country, with the percentages of adequacy below 50% in all regions, with the north region presenting the lowest percentage of adequacy, with only. In addition, another study[32] carried out in 2014 identified that the inadequacy of primary care for providing prenatal care was related to 40% of preventable infant and neonatal deaths in Brazil.

Neonatal deaths preventable by adequate care for the newborn corresponded to 30.7% of the total, with a decreasing trend, and deaths preventable by appropriate care during childbirth represented 18.1% of deaths in the period, with a steady trend. Studies that analyzed the historical series of the subject in question, according to regions of the country, also found results similar to those shown in this study [15,25].

A systematic review study with meta-analysis of observational studies to identify the main risk factors associated with neonatal deaths identified that factors related to childbirth, structure, and management of obstetric care, and newborn care are planned

and executed in an incipient and may determine an increase in unwanted neonatal outcomes, such as morbidity and mortality among this population[27].

Although they still represent a high percentage of preventable neonatal deaths, actions related to delivery and birth care have been the target of institutional actions in recent years, especially from 2011 with the implementation of the Stork Network Program, which aimed fundamentally at agreeing on actions for structuring places for obstetric care, training professionals for care, to reduce maternal and neonatal mortality. These actions contributed to the reduction of mortality from these causes over time, as demonstrated in this study[1,6,24].

In addition, the decreasing NMR, the second death that can be avoided by adequate care for the newborn, can be considered a result of the expansion of beds in the Neonatal Intensive Care Unit (NICU) in the country, especially in regions with the greatest deficit, incorporation of new technologies for NICU care, training of professionals in the light of scientific evidence. These actions allowed for the improvement of neonatal care and the avoidability of neonatal death, especially in the first hours after birth[1,2,4,27].

Neonatal mortality rates from other preventable causes were less frequent in the present study and all showed a downward trend, quite possibly thanks to programs related to child health, expansion of the FHS, and immunization, which are consolidated in the country and which contributed to the observed reduction on screen[23,27].

One of the main limitations of this study was the fact that it was not possible to extract, due to the unavailability in the DH system, maternal and neonatal data such as maternal age, mother's education, gestational age, type of delivery, birth weight, which are considered major factors for the assessment of neonatal mortality rates[27].

NMR is multidetermined and the factors associated with it go beyond the health sector, permeating socioeconomic issues, population education, empowerment of the female population, and cultural issues. In this way, the actions to face it must also happen from intersectoral and coordinated actions[24,27].

CONCLUSIONS

The results of this study revealed that there was a decrease in the neonatal mortality rate in Brazil, from 2015 to 2019, although the country still has rates considered high, given the numerous public policies and programs aimed at the qualification of maternal and child care, and which have been implanted and implemented in the country in the last decades.

Regarding the temporal trend analysis, the country presented a decreasing NMR in the analyzed period. On the other hand, in the geographic macro-regions, there was a decrease only in the Northeast and Midwest regions, with a stationary trend in the other regions, which allows us to discuss the need to qualify policies related to the health of mothers and children in the affected regions.

Concerning the analysis of deaths according to preventable causes, those that can reduce by adequate care during pregnancy, childbirth, and the newborn were the ones with the highest proportion, respectively. In the trend analysis, neonatal deaths that could reduce by appropriate care during pregnancy showed a steady state. Deaths that can avoid by proper care during childbirth and the newborn were decreasing. However, these findings reflect the low quality of prenatal care in Brazil already measured in large-scale studies, and reveal the urgent need to qualify managers and workers for adequate care for pregnant women in Primary Health Care.

Finally, the data analyzed in this research, originating from MIS and ISLB, both belonging to the Department of Health, can provide subsidies for the analysis of the health situation regarding neonatal mortality in Brazil and by regions, according to preventable causes, and thus, to qualify the analysis process of policies implemented in the field of maternal and child health, enabling the redefinition of actions when necessary.

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