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Socioeconomic and pathophysiological factors of infant mortality due to respiratory diseases

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ABSTRACT

OBJECTIVE

This study aims to analyze factors associated with infant and neonatal mortality from respiratory diseases in Brazil and in the Metropolitan Region of Sorocaba between 1996 and 2022.

METHODS

A descriptive and retrospective study was conducted using secondary data from DATASUS, considering mortality rates, age group, sex, race/ethnicity, maternal education, type of delivery, birth weight and gestational age.

RESULTS

A general decreasing trend in mortality was observed, with an average annual decline of 6.1%. However, higher rates persisted in areas with low income, inadequate sanitation and low maternal education, demonstrating the influence of social inequalities. The post-neonatal period (28–364 days) concentrated most deaths, particularly among male infants, reflecting biological vulnerabilities and exposure to environmental factors such as air pollution and passive smoking. The decline in mortality indicates the positive impact of public policies such as the Family Health Strategy and the National Immunization Program. Nevertheless, regional disparities remain, indicating the need to strengthen primary health care, expand vaccination coverage, promote exclusive breastfeeding and ensure timely access to pediatric emergency services.

CONCLUSION

These findings support the relevance of integrated and equitable health strategies, in line with Sustainable Development Goal 3, which aims to reduce infant and neonatal mortality by 2030.

KEYWORDS

Infant mortality; Neonatal mortality; Respiratory diseases; Socioeconomic factors; Public policies; Public health.

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INTRODUCTION

Historically, infant mortality has been recognized as one of the most significant social problems in the contemporary world, as it directly reflects the living conditions and the level of development of a society. The mortality rate of children under one year of age is an important public health indicator because it reveals not only access to and the quality of prenatal care, childbirth, and neonatal care, but also the socioeconomic inequalities that affect this extremely vulnerable population.[1]

According to the World Health Organization (WHO), acute respiratory infections are among the leading causes of death in children under five years of age worldwide.[2] Pneumonia, in particular, is one of the leading causes of preventable childhood mortality, especially in developing countries.[3] The immunological vulnerability of newborns, combined with factors such as malnutrition, inadequate sanitation, air pollution, and limited access to healthcare services, increases the risk of severe respiratory complications. Therefore, the prevention and proper treatment of these diseases are essential for reducing infant mortality and promoting a healthier start to life.[4]

In recent years, efforts to prevent infant mortality have been associated with several public health programs.[5] In September 2000, world leaders gathered in New York at the United Nations headquarters and approved the Millennium Declaration, which became known as the Millennium Development Goals (MDGs). These goals established a set of eight targets aimed at addressing the world's greatest development challenges by 2015, including reducing by two-thirds the mortality rate among children under five years of age. The implementation of this objective promoted a series of interventions and public health policies aimed at saving millions of children's lives through improvements in access to healthcare services, vaccination, nutrition, and basic sanitation.[6]

Continuing and expanding these objectives, in 2015 the United Nations established the Sustainable Development Goals (SDGs), a global initiative consisting of 17 interconnected goals and 169 specific targets designed to address the most urgent global challenges by 2030, including infant mortality. The United Nations estimates that there will be approximately 22.7 million neonatal deaths if each country reaches the target of 12 deaths per 1,000 live births by the established deadline.

The trajectory of child healthcare in Brazil has been developed over several decades and has undergone important transformations. Until the early 1980s, child health care was integrated with women's health services. It was only in 1984, with the creation of the Comprehensive Child Health Care Program (PAISC), that more specific and focused initiatives for childhood care began to emerge.[7]

Beginning in 1990, several programs and projects were implemented in Brazil to promote child health and well-being, including the creation of the Child and Adolescent Statute (ECA)[8], the Perinatal Health Care Program (PROASP)[9], food security and hunger reduction policies in 1993[10], the Integrated Management of Childhood Illness (IMCI, 1996)[11], and the National Neonatal Screening Program (PNTN, 2001).[12] In 2004, the Pact for the Reduction of Maternal and Neonatal Mortality and the National Committee for the Prevention of Infant and Fetal Death were also established. These initiatives, together with the Millennium Development Goals, actively contributed to efforts to reduce infant mortality rates.[13]

As a result, between 2000 and 2015 infant mortality decreased from 29 deaths per 1,000 live births to 13.8 deaths.[14] Globally, between 1990 and 2017 there was a 51% reduction in neonatal mortality rates.[15] However, according to the World Health Organization (WHO), approximately 6,700 newborns die every day, and despite the decline in deaths in recent years, 2.4 million children died during the first month of life in 2020, which remains a concerning public health issue.[16]

According to the Brazilian Ministry of Health (MH), the infant mortality rate is calculated based on the number of deaths among children under one year of age, while the neonatal mortality rate is based on deaths among infants aged 0 to 27 days. Neonatal mortality may be classified as early (0–6 days) or late (from the 7th day of life onward). Both indicators are calculated per 1,000 live births.

Among the causes of these deaths, many are considered preventable. Worldwide, different classifications of preventability have been proposed. Rutstein, a pioneer in the concept of preventable deaths, proposed a list of 90 causes that could potentially be prevented and, together with collaborators, concluded that such deaths generally serve as indicators of the quality of healthcare services.[17]

In Brazil, the Unified Health System (SUS) uses the Brazilian List of Preventable Causes (LBE), adapted by Malta and Duarte (2007), which identifies deaths that could be prevented through available health service interventions.[18] The Expanded Wigglesworth Classification (EWC) is also used in some studies; it evaluates the pathophysiological conditions and the timing of death in order to classify preventability into categories related to healthcare service interventions.[19]

Among the various causes of preventable deaths, respiratory diseases represent a significant group, particularly in low- and middle-income countries. Acute respiratory infections such as pneumonia and bronchiolitis are among the leading causes of death in children under five years of age, especially during the first year of life.[4] These conditions are largely preventable through strategies such as vaccination, exclusive breastfeeding, reduced exposure to environmental pollutants, and timely andadequate access to healthcare services.[20,21]

In Brazil, the persistence of deaths from respiratory causes reflects social inequalities, weaknesses in primary health care, and barriers to adequate healthcare access.[22] The seasonal nature of these infections, combined with exposure to risk factors such as air pollution and passive smoking, also contributes to the severity of clinical conditions and to mortality.[23] Therefore, infant deaths caused by respiratory diseases represent an important indicator of the effectiveness of public policies and the quality of healthcare provided within the Unified Health System (SUS).[24]

A child's probability of survival is strongly influenced by the place of birth, since some regions of the world still lack access to high-quality healthcare services, such as Sub-Saharan Africa and South Asia.[25] Data from UNICEF indicate that children in Africa are 15 times more likely to die before reaching one year of age compared to children in Europe and North America. A study on socioeconomic inequalities in infant mortality concluded that deaths occur more frequently among children born to low-income mothers,[26] reinforcing that socioeconomic status is one of the factors influencing infant mortality.

Interestingly, Alves and Coelho[27] reported that infant mortality affects boys more frequently than girls. Another study examining sex differences in fetal nutrition and growth found that although boys tend to gain more body mass than girls during pregnancy, they are also more vulnerable to intrauterine growth restriction (IUGR) and other complications in high-risk pregnancies.[28]

Although socioeconomic factors are strongly associated with infant mortality, pathophysiological factors are also directly related to these deaths. According to notification records from DATASUS, the main neonatal complications include prematurity, low birth weight, birth asphyxia, neonatal infections, respiratory distress syndrome, congenital malformations, malnutrition, and genetic diseases. It is also noteworthy that parasitic diseases such as malaria play a significant role in infant mortality, particularly in regions with unfavorable socioeconomic conditions.

A systematic review of global causes of mortality among children under five years of age between 2000 and 2015 found that the main causes were complications of preterm birth and pneumonia in countries with medium to high infant mortality rates, while congenital anomalies were the most important cause in countries with low and very low mortality rates.[29] Another descriptive crosssectional study reported that among 64 early neonatal deaths, 32 cases were caused by prematurity and 11 cases by birth asphyxia and infections, causes that could potentially have been prevented.[30]

Understanding vulnerability and regional causes of infant mortality has been essential for the development of prevention and health promotion programs aimed at neonatal and child populations. Thus, by analyzing data from recent decades on infant and neonatal mortality and examining possible associated factors, this study constructed a profile of the impacts of public policies implemented in recent years, compared these policies, and identified gaps that require greater attention. In this way, it becomes possible to better direct efforts toward

the prevention and treatment of socioeconomic and preventable causes of infant mortality, both at regional and national levels. In addition, this study was aligned with Target 3.2 of the Sustainable Development Goals (SDGs) established by the United Nations, which states: *"By 2030, end preventable deaths of newborns and children under five years of age, with all countries aiming to reduce neonatal mortality to at least 12 per 1,000 live births and under-five mortality to at least 25 per 1,000 live births.[31]

Thus, this study contributed to this global initiative by identifying the main factors associated with infant and neonatal mortality in the Sorocaba Metropolitan Region and across the national territory, to support prevention strategies and health promotion programs targeting this population.

METHODS

This study is an ecological, quantitative epidemiological time-series study with a retrospective design, conducted using population-based secondary data obtained from national health information systems. Data were collected through consultation of federal databases in order to characterize factors associated with infant and neonatal mortality due to respiratory diseases in the Sorocaba Metropolitan Region and throughout the national territory, analyzing their distribution over the period from 1996 to 2022.

Study Design

The study population consisted of children under one year of age who died between 0 and <12 months, according to place of occurrence and year.

To calculate the mortality rate, the direct method described in the infant mortality manual was used. This method calculates the number of deaths among residents aged 28 to 364 days multiplied by 1,000, divided by the number of live births among resident mothers.

All records were obtained from Live Birth Certificates available in the Live Birth Information System (SINASC) and from death records in the Mortality
Information System (SIM), both national databases maintained by the Brazilian Ministry of Health.

Ethical Considerations

This research did not require submission to a Research Ethics Committee (REC) because it was conducted using data collected from secondary databases publicly available on federal platforms, in accordance with Resolution No. 466 of December 12, 2012, of the Brazilian National Health Council.

Sources of Information

Data were collected from the Mortality Information System (SIM) and the Live Birth Information System (SINASC) to calculate the Infant Mortality Rate (IMR) and Neonatal Mortality Rate (NMR) through the Brazilian Unified Health System database (DATASUS).

Additionally, information was obtained from databases available in the Virtual Health Library (VHL), including the Latin American and Caribbean Health Sciences Literature (LILACS), the U.S. National Library of Medicine (MEDLINE/PubMed), the electronic library Scientific Electronic Library Online (SciELO), and Google Scholar.

Study Variables and Data Organization

The independent variables related to infant mortality included socioeconomic and demographic factors, such as age group (used to classify deaths as early neonatal, late neonatal, or post-neonatal), race/ethnicity, maternal age, maternal education level, gestational age, type of pregnancy, type of delivery, birth weight, and sex.

All data were obtained from the DATASUS platform. Data collection was organized into three time periods: 1996–2004, 2005–2013 e 2014–2022.

The analysis included the Sorocaba Metropolitan Region, which comprises the following municipalities: Alambari, Alumínio, Araçariguama, Araçoiaba da Serra, Boituva, Capela do Alto, Cerquilho, Cesário Lange, Ibiúna, Iperó, Itapetininga, Itu, Jumirim, Mairinque, Piedade, Pilar do Sul, Porto Feliz, Salto, Salto de Pirapora, São Miguel Arcanjo, São Roque, Sarapuí, Sorocaba, Tapiraí, Tatuí, Tietê, and Votorantim.

In addition, analyses were conducted across the five Brazilian geographic regions (North, Northeast, Midwest, Southeast, and South).

Statistical Analysis

Statistical analyses were performed using Microsoft Excel® software, applying the chi-square test (x^2) to evaluate associations between the analyzed variables.

The level of statistical significance adopted was $p < 0.05$, and results with values equal to or below this threshold were considered statistically significant.

RESULTS AND DISCUSSION

Respiratory diseases remain among the leading causes of infant mortality in Brazil and worldwide, particularly during the late neonatal and post-neonatal periods. Pneumonia, bronchiolitis, and complications of viral and bacterial infections contribute significantly to the burden of mortality among children under one year of age, despite advances achieved in recent decades through the expansion of vaccination coverage, strengthening of primary health care, and increased access to respiratory support technologies.[32-33]

The analysis presented here demonstrates that, between 1996 and 2022, deaths due to respiratory diseases among children under one year of age exhibited distinct regional patterns, although with several points of convergence reflecting both biological vulnerabilities and social and structural determinants of health.

A central finding of this study was the concentration of mortality in the postneonatal period (28–364 days) across all Brazilian regions, ranging from 93% to 95% of deaths, as shown in Table 1.

This finding suggests that respiratory diseases are more strongly associated with environmental exposure conditions, such as air pollution and passive smoking, inadequate nutrition, early weaning, and difficulties in timely access to health services, rather than with complications related to childbirth or the immediate neonatal transition.[34]

Silva et al. previously highlighted that mortality due to pneumonia and other acute respiratory infections is sensitive to primary health care performance, depending strongly on preventive measures and early diagnosis.[35]

Another notable finding was the predominance of male sex among deaths in all regions, which confirms findings in the literature regarding the greater immunological and pulmonary vulnerability of boys during the first year of life.[36]

According to a study on gender differences in respiratory morbidity and mortality among premature neonates, female fetuses and newborns tend to exhibit faster pulmonary maturation (greater surfactant expression and functionality, as well as accelerated alveolar and bronchiolar development) compared to males.

This biological difference results in a higher incidence of severe neonatal respiratory diseases among boys, including increased risk of respiratory distress syndrome (RDS), a greater need for ventilatory support, and a subsequent risk of bronchopulmonary dysplasia.[36]

Table 1 - Infant and neonatal mortality due to respiratory diseases according to the variables with the highest incidence across the regions of Brazil (1996–2022).

North				
	n	%	(O-E)^2 / E	p
Gestational age (37–41 weeks)	4.237	40,05%	12210,3	<0,05
Type of pregnancy (single)	7.138	67,48%	10212,1	<0,05
Type of delivery (vaginal)	5.441	51,44%	2200,2	<0,05
Birth weight (>2500 grams)	4.503	42,57%	2634,9	<0,05

Age group (28–364 days)	9.948	94,04%	17552,9	<0,05
Sex (male)	5.935	56,11%	160,5	<0,05
Race/ethnicity (mixed race)	5.438	51,41%	9408,4	<0,05
Maternal age (20–24 years)	2.396	22,65%	7732,7	<0,05
Maternal education (4–7 years)	2.072	19,59%	3773,4	<0,05
n = 10.578				
Northeast				
	n	%	(O-E)^2 / E	p
Gestational age (37–41 weeks)	6.719	27,75%	19242,3	<0,05
Type of pregnancy (single)	11.730	48,45%	16625,1	<0,05
Type of delivery (vaginal)	8.827	36,46%	7306,5	<0,05
Birth weight (>2500 grams)	7032	29,05%	9214,4	<0,05
Age group (28–364 days)	22.813	94,23%	40429,4	<0,05
Sex (male)	13.456	55,58%	318,8	<0,05
Race/ethnicity (mixed race)	9.906	40,92%	17998,2	<0,05
Maternal age (20–24 years)	3.905	16,13%	13291,6	<0,05
Maternal education (4–7 years)	3404	14,06%	9967,7	<0,05
n = 24.210				
South				
	n	%	(O-E)^2 / E	p
Gestational age (37–41 weeks)	3.071	37,60%	9720,5	<0,05
Type of pregnancy (single)	4.968	60,83%	17618,4	<0,05
Type of delivery (vaginal)	3.296	40,36%	8329,0	<0,05
Birth weight (>2500 grams)	3371	41,28%	1589,7	<0,05
Age group (28–364 days)	7.779	95,25%	14102,7	<0,05
Sex (male)	4.647	56,90%	155,8	<0,05
Race/ethnicity (mixed race)	5.338	65,36%	13425,4	<0,05
Maternal age (20–24 years)	1.633	20,00%	3505,4	<0,05
Maternal education (4–7 years)	1530	18,73%	3194,4	<0,05
n = 8.167				
Southeast				
	n	%	(O-E)^2 / E	p
Gestational age (37–41 weeks)	6.505	22,00%	19303,8	<0,05
Type of pregnancy (single)	13.661	46,21%	19433,1	<0,05
Type of delivery (vaginal)	8.346	53,94%	559,7	<0,05
Birth weight (>2500 grams)	7.517	25,42%	9909,2	<0,05
Age group (28–364 days)	27.569	93,25%	57660,3	<0,05
Sex (male)	16.671	56,39%	487,6	<0,05
Race/ethnicity (mixed race)	13.551	45,83%	25063,1	<0,05
Maternal age (20–24 years)	5.014	16,96%	16086,5	<0,05
Maternal education (8–11 years)	4.517	32,23%	13741,9	<0,05
n = 29.566				
Midwest				
	n	%	(O-E)^2 / E	p
Gestational age (37–41 weeks)	2.014	37,52%	5620,8	<0,05
Type of pregnancy (single)	3.352	62,44%	4592,5	<0,05
Type of delivery (vaginal)	2.149	40,03%	801,6	<0,05
Birth weight (>2500 grams)	2.162	40,28%	1218,7	<0,05
Age group (28–364 days)	5.088	94,78%	9128,1	<0,05
Sex (male)	3.043	56,69%	97,7	<0,05
Race/ethnicity (mixed race)	1.732	32,27%	3029,1	<0,05
Maternal age (20–24 years)	1.070	19,93%	3489,3	<0,05
Maternal education (4–7 years)	1.035	19,28%	2192,4	<0,05
n = 5.368				

Distribution of factors associated with infant mortality across the regions of Brazil and results of the chi-square test. Values are expressed as absolute numbers, percentages, chi-square components ((O-E)2/E), and significance level (p).

Source: prepared by the author using data from the Brazilian Ministry of Health - DATASUS.

Among the deaths analyzed, a relevant proportion of children had adequate birth weight (>2500 g), particularly in the Northeast (29.05%) and Southeast (25.42%). This finding demonstrates that mortality due to respiratory diseases is not limited to low birth weight or premature newborns, but also affects children born within the range considered adequate. This reinforces the role of socioenvironmental conditions, caregiving practices, and the responsiveness of the health system.[37]

Racial and regional inequalities also emerged as relevant determinants. While the North and Northeast showed higher mortality among mixed-race (brown) children, in the South, Southeast, and Midwest there was a predominance among white children. This result reflects the demographic composition of the regions but also suggests that the impact of childhood respiratory diseases follows patterns of social vulnerability and unequal access to healthcare services. National studies have indicated that mixed-race and Black children face a greater risk of delays in care and reduced access to higher-complexity health services,[38] which may increase the lethality of potentially preventable and treatable respiratory conditions.

Maternal education showed a strong association across all regions. In contexts with lower levels of education (North, Northeast, and Midwest), the predominant category was 0–7 years of schooling, whereas in the Southeast there was a higher frequency of mothers with 8–11 years of education. Despite these variations, low or intermediate maternal education was associated with higher mortality in all scenarios. The literature indicates that mothers with lower educational attainment may have greater difficulty recognizing early signs of disease severity, lower adherence to protective practices such as exclusive breastfeeding, and more barriers to seeking timely and appropriate healthcare.[39]

It is important to highlight that this study identified a high proportion of records classified as “ignored” in several variables available in DATASUS. This limitation reflects weaknesses in the completeness and quality of information recorded in national surveillance systems, such as the Mortality Information System (SIM) and the Live Birth Information System (SINASC). These systems frequently present inconsistencies resulting from incomplete form completion, lack of standardization, and operational challenges within health services. For this reason, such records were excluded from statistical analyses in order to reduce potential interpretative bias and ensure the reliability of the statistical results.

Finally, the analysis confirms that infant mortality due to respiratory diseases in Brazil remains highly sensitive to public health policies. The substantial reduction observed in previous decades has been largely attributed to the expansion of Primary Health Care,[40] the strengthening of the Family Health Strategy,[41] and the consolidation of the National Immunization Program, which contributed to reductions in pneumonia and other acute respiratory infections.[32,42] These advances align with the global agenda of the Sustainable Development Goals

(SDGs), particularly SDG 3, which establishes the target of reducing infant mortality to no more than 12 deaths per 1,000 live births by 2030.[43,44]

In this context, the Brazilian experience demonstrates the relevance of integrating immunization policies, health surveillance, and primary health care as central strategies for achieving international targets. However, the persistence of regional and socioeconomic inequalities represents a significant challenge, indicating that the maintenance of universal and equitable policies is essential to ensure the continued reduction of infant mortality.[43,45]

According to Table 2, it is possible to observe a sustained reduction in infant and neonatal mortality rates due to respiratory diseases in Brazil, with an average annual reduction of approximately 6.1%. This decline is consistent with the impact of public health interventions implemented over recent decades. Previous studies have also reported substantial reductions in mortality from pneumonia and other respiratory infections in middle-income countries that expanded vaccination coverage and basic health services.[33]

Table 2 - Infant mortality rate by region and study periods in Brazil.

Regions	Group A (1996-2004)	Group B (2005 a 2013)	Group C (2014-2022)
Sorocaba	1,38	0,60	0,27
Metropolitan Region of Sorocaba	1,52	1,09	0,73
North	1,64	1,29	0,98
Northeast	1,59	0,95	0,55
Southeast	1,58	0,71	0,46
South	1,38	0,52	0,29
Midwest	1,26	0,82	0,51
Brazil	1,54	0,83	0,52

The infant mortality rate was calculated as the number of deaths among children under one year of age per 1,000 live births in each period and region (infant mortality = [deaths <1 year / live births] × 1,000).

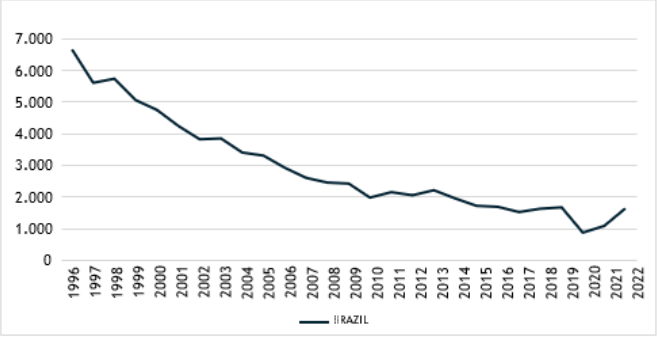
Source: Brazilian Ministry of Health, Live Birth Information System (SINASC) and Mortality Information System (SIM), Brazil.

It can be observed in Figures 1 and 2 that the decline was not linear throughout the entire study period. These points require careful interpretation, since 2020 marked the beginning of the COVID-19 pandemic, which altered mortality dynamics, healthcare-seeking behavior, and reporting practices. Part of the apparent reduction may reflect changes in notification systems, variations in exposure to respiratory pathogens due to social distancing measures, or underreporting, whereas the subsequent increase may be associated with the return of seasonal respiratory pathogens or changes in access to healthcare services and surveillance practices. Therefore, specific investigation for the years 2020–2022 is recommended.

However, data from 1996–2022 indicate that these advances were not sufficient to eliminate regional and social inequalities. Gaps remain in the surveillance of the post-neonatal period, in the quality of primary health care, and in the equity of access to hospital services.

Thus, the findings suggest that the sustained reduction of mortality due to respiratory diseases requires region-specific approaches, combining structural improvements, sanitation, nutrition, and education, with targeted public health strategies, such as strengthening primary health care, active monitoring of high-risk infants, promotion of exclusive breastfeeding, and expansion of access to pediatric emergency services.

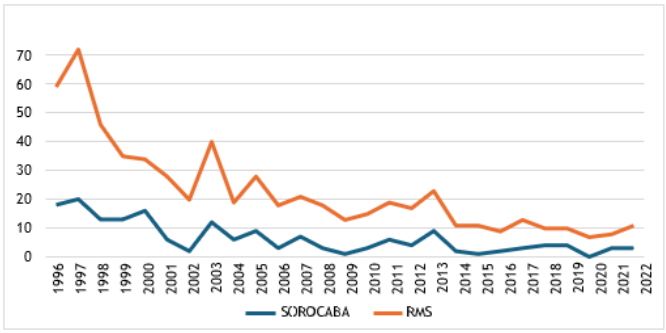
Figure 1 - Evolution of infant mortality in Brazil (1996–2022).



The figure presents the absolute number of infant deaths (<1 year) recorded annually across the national territory.

Source: Prepared by the author using data from the Mortality Information System (SIM). Brasília: Ministry of Health; 2023.

Figure 2 - Evolution of infant mortality in Sorocaba and the Sorocaba Metropolitan Region (1996–2022).



The figure presents the absolute number of infant deaths (<1 year) recorded annually in the municipality of Sorocaba and in the Sorocaba Metropolitan Region.

Source: Prepared by the author using data from the Mortality Information System (SIM). Brasília: Ministry of Health; 2023.

CONCLUSION

Infant and neonatal mortality due to respiratory diseases in the Sorocaba Metropolitan Region and in Brazil decreased between 1996 and 2022, reflecting the impact of public health policies such as Primary Health Care, the Family Health Strategy, and the National Immunization Program. It was also observed that socioeconomic factors, low maternal education, and regional inequalities influence the incidence of deaths. Despite limitations resulting from records classified as “ignored” in the DATASUS database, the findings reinforce the importance of integrated and equitable health strategies aligned with Sustainable Development Goal (SDG) 3 to ensure the continued reduction of infant and neonatal mortality.

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