Spatial and temporal patterns of infant mortality and its components in Rio de Janeiro

Padrões espaciais e temporais da mortalidade infantil e seus componentes no Rio de Janeiro

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ABSTRACT Objectives. The study aims to assess the trend of neonatal, post-neonatal, and infant mortality from 1996 to 2020 within the metropolitan region of the state of Rio de Janeiro and other regions. Methods. Ecological study using the region as analysis unity. Data were accessed from the Mortality Information System and Live Birth Information System in the capital Rio de Janeiro, in the neighboring areas of Niterói, São Gonçalo, Baixada Fluminense, and the remaining regions of the state of Rio de Janeiro State. We applied Poisson multilevel modeling, where the models' response variables were infant mortality and its neonatal and post neonatal components. Fixed effects of the adjusted models were region and death year variables. Results. During the 1996-2020 period, the Baixada Fluminense showed the highest infant mortality rate as to its neonatal and post neonatal components. All adjusted models showed that the more recent the year the lower the mortality risk. Niterói showed the lowest adjusted risk of infant mortality and its neonatal and post neonatal components. Conclusion. Baixada Fluminense showed the highest mortality risk for infant mortality and its neonatal and post-neonatal components in the metropolitan region. The stabilization in mortality rates in recent years was identified by the research.

KEYWORDS Infant mortality. Epidemiology. Longitudinal studies. Multilevel analysis. Spatial analysis.

RESUMO *Objetivos. Avaliar a tendência da mortalidade neonatal, pós-neonatal e infantil de 1996 a 2020, na região metropolitana do estado do Rio de Janeiro e nas outras regiões. Métodos. Estudo ecológico utilizando regiões como unidade de análise. Os dados foram acessados no Sistema de Informações sobre Mortalidade e Sistema de Informações sobre Nascidos Vivos da Capital (Rio de Janeiro), dos territórios vizinhos (Niterói, São Gonçalo e Baixada Fluminense) e das outras regiões do Estado do Rio de Janeiro. Utilizamos a modelagem multinível de Poisson, onde as variáveis de resposta dos modelos foram mortalidade infantil e seus componentes neonatal e pós-neonatal. Os efeitos fixos dos modelos ajustados foram região e ano da morte. Resultados. No período 1996-2020, a Baixada Fluminense apresentou a maior taxa de mortalidade infantil de seus componentes neonatal e pós-natal na região metropolitana. Todos os modelos ajustados mostraram que quanto mais recente o ano, menor o risco de mortalidade. O risco ajustado da mortalidade infantil e seus componentes neonatal e pós-neonatal foi menor em Niterói. Conclusão. A Baixada Fluminense apresentou o maior risco de mortalidade infantil e de seus componentes neonatal e pós-neonatal na região metropolitana. Detectamos estabilização das taxas de mortalidade nos últimos anos.*

PALAVRAS-CHAVE *Mortalidade infantil. Epidemiologia. Estudo longitudinal. Análise multinível. Análise espacial.*

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Introduction

Infant mortality measures the occurrence of deaths within the first year of life, while its two components, neonatal and post neonatal, measure the deaths during the first 27 days of life and the deaths between the 28th and the 364th, respectively[1].

The infant mortality rate is an indicator of a population's quality of life and level of development. Most deaths occur within the first year of life, especially during the first month. Perinatal mortality from causes such as prematurity is still quite high. Factors related to pregnancy, childbirth, congenital syphilis, and the puerperium, generally preventable with more qualified care, are related to these causes[2]. The mortality in the first week of life depends mainly on technology, given the need for a neonatal intensive care unit. It is also influenced by maternal conditions, which, if properly administered in primary or specialized care, can reduce perinatal infections, prematurity, low birth weight, and other problems, avoiding the need of high technology for newborns[2]. Post-neonatal mortality can also be reduced by actions aimed at primary care, in addition to the development of intersectoral actions that address socio-economic and environmental issues, such as basic sanitation[3].

Within the metropolitan area of Rio de Janeiro State, the cities of Niterói and Rio de Janeiro show the highest Human Development Index (HDI), respectively 0.84 and 0.80, while the average HDI in Baixada Fluminense is 0.70, as for 2010 data[4]. The average monthly income per capita in the cities of Niterói and Rio de Janeiro is also the highest in the state, respectively 1951 and 1422 reais, while the average income of the municipalities in the Baixada Fluminense is 550 reais, as for 2010 data[5].

Considerable progress has been made in reducing infant deaths worldwide over the last decades. The infant mortality rate in the United States decreased from 2017 to 2018, varying from 5.8/1,000 to 5.7/1,000[6]. The reduction of poverty and the expansion of health care caused infant mortality to decrease in many countries. However, Sub-Saharan Africa still depicts very high levels of infant mortality, although also experiencing significant reductions in infant mortality rates, which varied from 106.6/1,000 in 1990 to 51.7/1,000 in 2019[7]. In poor countries, the greater challenge is to reduce neonatal mortality. In Tanzania, for example, there was little variation in neonatal mortality rates from 2004 (27/1,000) to 2016 (22/1.000). However, post neonatal mortality rates showed a significant reduction, from 35/1,000 in 2004 to 16/1,000 in 2016[8]. In developed countries, these mortality rates are lower. In the United States, for example, the population groups showing the highest mortality rates, e.g. blacks and indigenous people, neonatal and post neonatal death rates were 7.16/1,000 and 4.41/1,000, respectively (2017)[9].

Infant mortality rates in Brazil have declined in the last three decades. However, they can still be considered high in some regions of the country as per international standards[10]. From 2003 to 2017, the infant mortality rate in Brazil varied from 22.5/1,000 in 2003 to 13.4/1,000 in 2017[11].

From 2000 to 2013, the preventable mortality rates in southeastern Brazil reduced 4.5%. The reduction was attributed to the better quality of care during childbirth[12]. The Northeast is one of the regions showing the highest percentage of preventable deaths. Data from 1980 to 2012 indicate that almost 80% of deaths in the region are considered preventable and 51% could be reduced with adequate care during pregnancy[13]. Improving the Health System contributes to reducing preventable infant mortality. Prenatal quality is critical to avoiding preventable pregnancy deaths.

The reduction of some preventable mortality causes, such as the reduction of the newborn respiratory distress syndrome, intrauterine hypoxia, asphyxia at birth, and neonatal aspiration syndrome, detected in southeastern Brazil from 2000 to 2013, seems to have brought about positive effects in the reduction of infant mortality[12]. Data indicate

a sharp decrease in infant mortality and its neonatal and post neonatal components, not only in the Southeast Region but also in Brazil as a whole[14]. On the other hand, there is some evidence that mortality levels stopped decreasing between 2015 and 2016[15]. This study aimed to assess the tendency of neonatal, post neonatal, and infant mortality among metropolitan regions of the state of Rio de Janeiro and other regions of the state from 1996 to 2020.

Material and methods

This is an ecological study using public data from the Mortality Information System (SIM) and the Live Birth Information System (SINASC), available on the website of the Informatics Department of the Unified Health System. We used the territorial geo-referenced mesh of Brazilian municipalities (shapefile file), available on the website of the Instituto Brasileiro de Geografia e Estatística (IBGE).

For each selected region, we assessed the number of neonatal, post neonatal, and infant deaths, as well as the number of live births from 1996 to 2020, and calculated the annual rate of mortality per 1,000 live births.

The long study period of 24 years was chosen so to increase the consistency of the findings. To easy the envisage the descriptive analysis of mortality rates by period, both in the table and in choropleth maps, we opted to use five-year period mobile data, as per 1996-2000, 2001-2005, 2006-2010, 2011-2015, and 2016-2020.

The analysis unity is the region. The study focused on the investigation of the city of Rio de Janeiro and the adjacent territories that form its metropolitan region – Niterói, São Gonçalo, and Baixada Fluminense. Baixada Fluminense itself comprises a set of municipalities – Belford Roxo, Duque de Caxias, Itaguaí, Japeri, Magé, Mesquita, Nilópolis, Nova Iguaçu, Paracambi, Queimados, São João de Meriti and Seropédica. The rates of the other regions of the state of Rio de Janeiro – Leste Fluminense, excluding the municipalities of Niterói and São Gonçalo; Baia da Ilha Grande; Baixada Litorânea; Centro-Sul; Médio Paraíba; Noroeste; Norte; and Serrana – were compared to Rio de Janeiro City and its adjacent regions.

The state of Rio de Janeiro is located in the southeastern of Brazil. Its capital is Rio de Janeiro City, one of the main cities of the country, whose total of inhabitants reached 6,625,849 in 2022. Niterói City is near Rio de Janeiro City and is the second most important city in the state, totaling 523,664 inhabitants in 2022. Neighboring these large cities, the Baixada Fluminense region and the municipality of São Gonçalo stand out with 929,446 and 3,419,577 inhabitants in 2022, respectively, as they are highly populated areas with worse socioeconomic conditions. It was decided to investigate the municipalities of the Baixada Fluminense as a whole, and not as single municipalities, since, in general, the region comprises municipalities facing a disorderly occupation of the urban population pertaining to the city of Rio de Janeiro that avoid the high property prices of the capital[16]. The municipalities of Baixada are also known as 'dormitory cities', as they are highly dependent on the capital for matters such as employment, specific medical exams, and hospitals.

From statistical analysis, median and interquartile ranges were used to describe mortality rates. As to compare mortality rates between regions and periods, we used the Kruskal test and pairwise comparisons, applying Kruskal Dunn's test for multiple comparisons of independent samples, and the Holm P-value adjustment method.

We carried out Poisson multilevel modeling, with the following random effects: region (intercept), death year (slope), and death year square term (slope). Separate models were built to explain neonatal, post neonatal, and infant mortality. Fixed effects of the three adjusted models were region, death year, and death year square term. We also included an offset with the logarithm of the live births.

We calculated the deviance and standard deviation of the random effects for null and adjusted models and used analysis of variance to test the improvement of model specification by including random effects.

We used area data analysis to spatially describe the infant mortality rate by choropleth maps over the period. So to assess the spatial dependence, we calculated Univariate Moran's Local I and built Lisa Cluster Maps using Queen contiguity Weight (order of contiguity = 1).

Graphical models were constructed to supplement the analysis. The software R-Project (version 4.2.3), GeoDa (version 1.4.6), and QGIS (version 3.16) were used in the analysis.

Results

Over the period 1996-2020, within the metropolitan region, the highest rate of infant mortality and its neonatal and post neonatal components was observed in Baixada Fluminense, whose rates reached 18.79/1,000 for infant mortality, 12.44/1,000 for neonatal mortality, and 6.33/1,000 for post neonatal mortality. The post neonatal mortality rate in Baixada Fluminense was the highest of any region of the State. However, the Centro-Sul region overcame the Baixada Fluminense rates of infant and neonatal mortality, while the Norte region also overcame the Baixada Fluminense rates of neonatal mortality (*table 1*).

Table 1. Distribution of neonatal, postneonatal and infant mortality rates by the period in Rio de Janeiro, Niterói, São Gonçalo, and other regions of Rio de Janeiro State, 1996-2020

Region	Annual rate 1996-2020	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	P-value
			Median Coefficient /1,000 live births (IQR)				
Rio de Janeiro							
Neonatal	9.58	12.01 (1.41)	10.53 (0.30)	8.73 (0.26)	7.92 (0.60)	7.99 (0.50)	0.0003
Post neonatal	4.94	6.16 (0.59)	4.90 (0.29)	4.88 (0.30)	4.31 (0.51)	3.93 (0.41)	0.0007
Infant	14.53	18.19 (1.41)	15.43 (0.30)	13.72 (0.26)	12.55 (0.60)	12.10 (0.50)	0.0002
Niterói							
Neonatal	9.30	12.09 (0.62)	11.31 (1.15)	9.05 (1.33)	6.55 (1.49)	6.79 (0.93)	0.0005
Post neonatal	4.25	5.58 (0.83)	4.22 (0.49)	3.34 (0.64)	3.87 (1.00)	3.85 (0.25)	0.003
Infant	13.55	17.24 (1.44)	15.53 (1.84)	13.11 (2.28)	10.51 (0.21)	9.98 (1.08)	0.0004
São Gonçalo							
Neonatal	10.47	13.55 (1.26)	11.05 (0.72)	10.15 (0.36)	8.03 (0.84)	7.98 (0.21)	0.0003
Post neonatal	4.60	4.86 (0.47)	4.21 (0.53)	4.70 (1.05)	4.15 (0.65)	4.89 (0.49)	0.15
Infant	15.10	18.41 (1.85)	15.38 (0.47)	14.09 (1.03)	12.11 (1.26)	12.75 (1.65)	0.0005
B Fluminense							
Neonatal	12.44	16.41 (5.35)	13.30 (2.90)	10.55 (3.02)	9.39 (2.57)	9.76 (2.54)	0.0001
Post neonatal	6.33	8.53 (3.78)	6.39 (1.72)	4.95 (1.67)	5.27 (1.68)	5.18 (1.72)	0.0001
Infant	18.79	25.97 (8.19)	19.77 (4.75)	15.69 (3.00)	14.25 (3.38)	14.98 (3.50)	0.0001
L Fluminense							
Neonatal	10.90	13.12 (5.86)	12.42 (4.00)	10.55 (4.30)	7.96 (4.89)	7.91 (4.15)	0.0001
Post neonatal	4.66	5.09 (3.35)	3.93 (4.07)	4.04 (3.43)	4.06 (3.50)	4.10 (2.13)	0.09
Infant	15.56	20.12 (5.89)	17.29 (7.83)	14.91 (4.38)	13.11 (4.86)	10.83 (4.11)	0.0001
Baia I Grande							
Neonatal	9.41	17.01 (1.65)	8.22 (0.93)	6.57 (1.36)	8.29 (0.93)	7.11 (2.32)	0.007

Table 1. Distribution of neonatal, postneonatal and infant mortality rates by the period in Rio de Janeiro, Niterói, São Gonçalo, and other regions of Rio de Janeiro State, 1996-2020

Region	Annual rate 1996-2020	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	P-value
				Median Coefficient /1,000 live births (IQR)			
Post neonatal	4.65	5.97 (1.97)	4.14 (2.74)	4.82 (0.35)	4.01 (1.07)	4.33 (2.16)	0.02
Infant	14.08	23.03 (3.12)	12.96 (3.76)	11.32 (0.27)	12.45 (0.48)	11.94 (4.68)	0.01
B Litorânea							
Neonatal	10.18	15.88 (3.65)	11.09 (1.18)	9.31 (0.37)	7.86 (0.45)	8.30 (0.74)	0.0009
Post neonatal	4.32	7.63 (1.90)	4.14 (0.34)	3.37 (0.50)	3.47 (0.08)	3.41 (0.56)	0.007
Infant	14.53	22.27 (2.26)	14.34 (1.03)	12.58 (0.47)	11.75 (1.12)	12.23 (1.06)	0.0009
Centro-Sul							
Neonatal	13.80	19.09 (7.62)	14.93 (5.41)	11.31 (1.84)	8.75 (0.43)	11.07 (2.45)	0.0009
Post neonatal	5.41	9.45 (3.08)	5.26 (1.18)	3.43 (1.08)	4.80 (0.95)	2.59 (1.31)	0.004
Infant	19.21	28.54 (4.99)	20.19 (7.52)	14.91 (2.01)	12.88 (1.95)	14.22 (1.89)	0.001
Médio Paraíba							
Neonatal	11.84	16.99 (0.72)	14.26 (1.96)	10.33 (1.31)	8.58 (1.13)	8.70 (0.12)	0.0005
Post neonatal	4.56	6.70 (0.41)	4.69 (0.54)	4.37 (0.28)	3.47 (0.74)	3.30 (0.75)	0.003
Infant	16.42	23.68 (0.84)	19.37 (0.84)	14.04 (1.41)	12.22 (1.01)	11.90 (0.43)	0.0004
Noroeste							
Neonatal	11.67	16.39 (1.51)	11.99 (3.08)	11.32 (2.34)	8.69 (1.77)	9.50 (0.36)	0.001
Post neonatal	4.64	8.59 (3.16)	4.44 (1.07)	4.19 (1.33)	3.01 (0.51)	3.31 (2.35)	0.05
Infant	16.32	22.48 (2.92)	17.67 (2.99)	15.51 (4.35)	11.44 (1.13)	13.02 (2.61)	0.001
Norte							
Neonatal	12.90	19.28 (1.07)	13.37 (3.54)	10.52 (0.67)	10.34 (0.33)	9.69 (1.97)	0.0009
Post neonatal	5.84	10.19 (1.79)	5.72 (0.13)	5.30 (0.54)	4.26 (0.23)	4.33 (1.31)	0.001
Infant	18.76	30.19 (1.62)	19.70 (3.87)	15.68 (0.44)	14.68 (0.53)	13.70 (0.68)	0.0003
Serrana							
Neonatal	12.12	15.98 (1.03)	13.10 (0.69)	10.81 (0.40)	10.50 (1.47)	8.58 (0.43)	0.0002
Post neonatal	4.76	6.88 (1.55)	4.69 (0.12)	4.16 (0.19)	3.74 (0.91)	3.07 (0.40)	0.0003
Infant	16.89	23.73 (1.29)	17.89 (0.66)	14.94 (0.38)	14.90 (2.07)	11.66 (0.44)	0.0002

Source: Own elaboration.

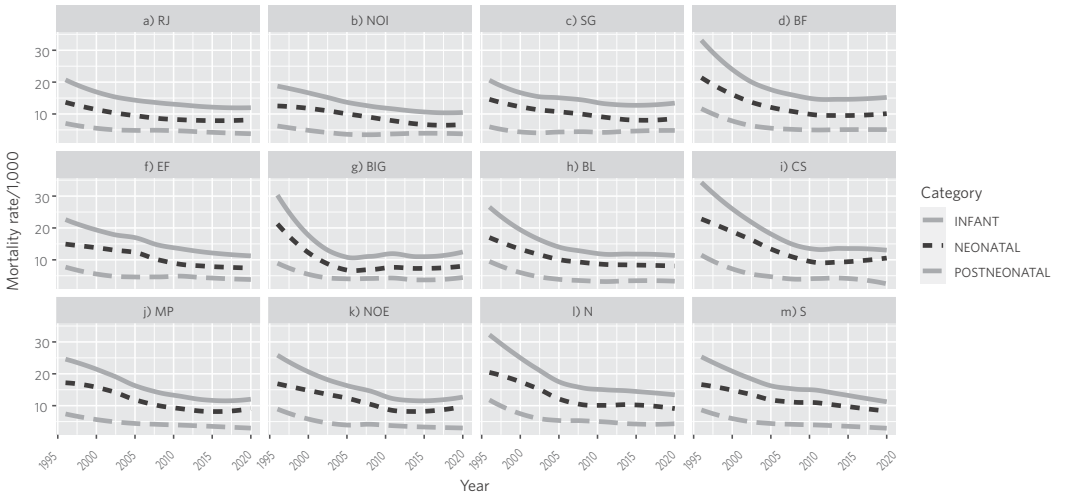
IQR = interquartile range; B Fluminense = Baixada Fluminense; L Fluminense = Leste Fluminense excluding the municipalities of Niterói and São Gonçalo; Baia I Grande = Baia da Ilha Grande; B Litorânea = Baixada Litorânea.

Note: Kruskal Wallis tests were used to compare the rates.

According to pairwise comparisons of Kruskal Dunn's test for multiple comparisons, infant and post neonatal mortality rates are statistically higher in Baixada Fluminense compared to all the regions of metropolitan areas (p-value<0.05). The rates in Baixada Fluminense were statistically higher for neonatal mortality than in Rio de Janeiro and Niterói (p-value<0.004), noting that the results are not shown in the tables.

Main trends of neonatal, post neonatal, and infant mortality suggest their decreasing over time, showing a tendency toward the stabilization of rates in recent years (*figure 1*). Baixada Fluminense rates for infant, neonatal, and post neonatal mortality respectively decreased 53.26%, 42.37 %, and 57.45% from 1996 to 2020.

Figure 1. Distribution of neonatal, post neonatal, and infant mortality by region of Rio de Janeiro State, 1996-2020

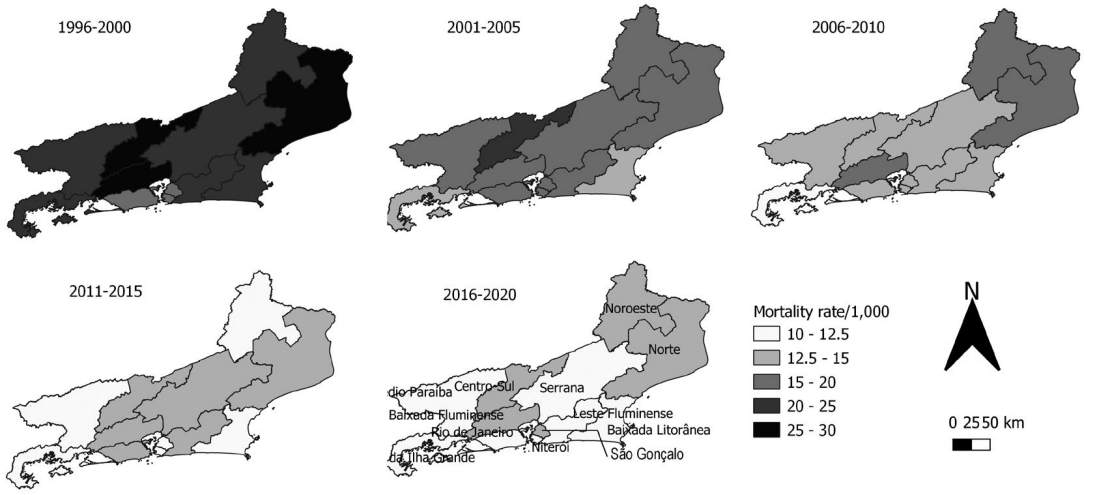


A progressive decline was observed in infant mortality rates and its neonatal component in all regions over time. In most regions, the greatest reduction in mortality rates occurred between the first two periods. For example, Baixada Fluminense showed a reduction of 23.87% in infant mortality between the first two periods, and a small reduction of 9.17% between the third and the fourth periods (*table 1*). Mostly, Baixada Fluminense, Baia de Ilha Grande, Centro-Sul, and Norte regions showed the sharpest reduction in rates over the first years of the period (*figure 1, table 1*).

According to pairwise comparisons of Kruskal Dunn's test for multiple comparisons, there was a reduction in most mortality rates over the period. Except for the post neonatal mortality rate in São Gonçalo and the regions of Leste Fluminense and Noroeste, all mortality rates were statistically higher in the first period compared to the last (p-value>0.05), noting that the results are not shown in the tables.

Figure 2 depicts the gradual reduction in the state of Rio de Janeiro as for infant mortality rates over the periods. The first period (1996-2000) revealed mortality rates between 20 and 30 deaths per 1,000 prevail, except for Rio de Janeiro, Niterói, and São Gonçalo. The second period (2001-2005) rates do not exceed 20/1,000, except for the Centro-Sul region. The third period (2006-2010) rates stay below 15/1,000 in most regions. The fourth period (2011-2015) rates are kept below 15/1,000. As for the last period (2016-2020), most regions rates remained below 12.5/1,000.

Figure 2. Distribution of infant mortality rate in Rio de Janeiro State over the time, 1996-2020

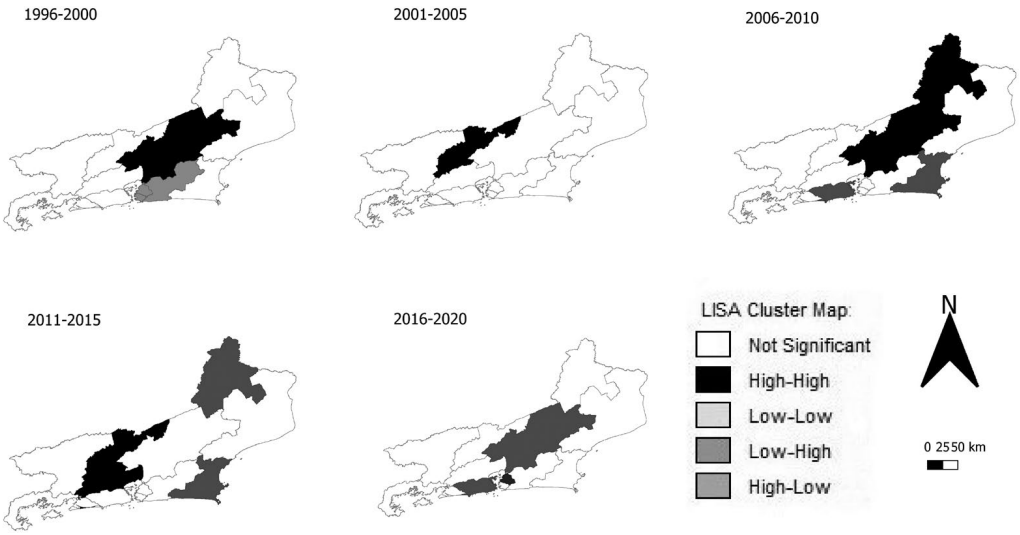


N = North; km = Kilometers.

Moran's Local I for infant mortality was 0.25 in the first period, indicating low spatial dependence, and rates of neighboring areas similar to each other. The second, third, and fourth periods showed a Moran's Local I of respectively -0.13, -0.14, and -0.16, indicating low spatial dependence, and different rates of neighboring areas. As for the last period, Moran's Local I stayed close to zero (0.04), indicating an absence of spatial autocorrelation, noted the results are not shown in tables and figures.

Figure 3 shows the spatial cluster areas. During the first period, Leste Fluminense appears as a region with a low infant mortality rate, surrounded by other regions with low rates, while the Serrana region appears as an area with a high mortality rate, surrounded by other regions with high rates. As to the second period, the Centro-Sul region appears as an area with a high mortality rate, surrounded by other regions with high rates. The third period reveals two regions as areas with a high mortality rate, surrounded by other regions with high rates, Serrana and Noroeste. Rio de Janeiro and Baixada Litorânea appear as transition zones, with low rates, but surrounded by regions with high rates. Within the fourth period, the Baixada Fluminense and the Centro-Sul appear as areas with a high mortality rate, surrounded by other regions with high rates, while the Baixada Litorânea and the Noroeste appear as transition zones, showing low rates, but surrounded by regions with high rates. The last period displays Rio de Janeiro and the Serrana region as transition areas, showing low rates, but surrounded by regions with high rates. São Gonçalo also appears as a transition zone, but showing high rates and surrounded by regions with low rates.

Figure 3. Distribution of the clusters of infant mortality rate in the state of Rio de Janeiro over the period 1996-2020



N = North; km = Kilometers.

The adjusted analysis also showed that Baixada Fluminense was the region with the highest risk as to post neonatal mortality (*table 2*). As for neonatal mortality, Norte and Centro-Sul showed a mortality risk of respectively 6% and 11% higher than Baixada Fluminense. As for infant mortality, there was no difference among the mortality risk of Baixada Fluminense, Centro-Sul and Norte regions, but the risk in Baixada Fluminense was higher than in all the others regions. The adjusted risk of infant mortality and its components neonatal and post neonatal was lower in Niterói. There was a reduction in the risk of death over the period for infant mortality and its components.

The evidence suggests that the better specification model includes the random effects of the region (intercept), death year (slope), and death year square term (slope) (*table 2*).

Table 2. Crude and adjusted rate ratio of neonatal, postneonatal, and infant mortality in Rio de Janeiro State, 1996-2020

	Neonatal				Postneonatal				Infant			
	Crude		Adjusted		Crude		Adjusted		Crude		Adjusted	
Fixed effect	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**
Region												
BF	1		1		1		1		1		1	
RJ	0.79	***	0.77	***	0.78	***	0.78	***	0.80	***	0.78	***
NOI	0.75	***	0.75	***	0.67	***	0.67	***	0.74	***	0.72	***
SG	0.85	***	0.83	***	0.71	***	0.71	***	0.83	***	0.80	***
LF	0.88	***	0.89	***	0.74	***	0.74	***	0.85	***	0.84	***
BIG	0.72	***	0.77	***	0.75	***	0.75	***	0.71	***	0.76	***

Table 2. Crude and adjusted rate ratio of neonatal, postneonatal, and infant mortality in Rio de Janeiro State, 1996-2020

	Neonatal				Postneonatal				Infant			
	Crude		Adjusted		Crude		Adjusted		Crude		Adjusted	
Fixed effect	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**	**RR**	**P-v**
BL	0.85	***	0.86	***	0.72	***	0.73	***	0.79	***	0.82	***
CS	1.06	•	1.11	**	0.84	**	0.85	**	0.95	•	1.02	NS
MP	0.93	**	0.95	*	0.72	***	0.72	***	0.87	***	0.87	***
NOE	0.93	*	0.93	*	0.72	***	0.73	***	0.84	***	0.86	***
N	1.04	•	1.06	**	0.94	•	0.94	NS	0.98	NS	1.02	NS
S	0.99	NS	0.97	NS	0.74	***	0.74	***	0.91	*	0.89	***
Year	0.97	***	0.97	***	0.98	•	0.97	***	0.97	***	0.97	***
Year^2	1.00	NS	1.00	***	1.00	•	1.00	***	1.00	NS	1.00	***

Random effect						
	Std. Dev.		**Std. Dev.**		**Deviance**	
	Null model	**P-v**	**Adj model**	**P-v**	**Null model**	**Adj model**
Neonatal					4818	4718
Region (inter)	0.24	***	0.06	***		
Year (slope)	0.03	***	0.004	***		
Year2 (slope)	0.002	***	0.001	***		
Postneonatal					4142	4069
Region (inter)	0.11	***	0.06	***		
Year (slope)	0.03	***	0.01	***		
Year2 (slope)	0.002	***	0.001	***		
Infant					5158	5063
Region (inter)	0.12	***	0.05	***		
Year (slope)	0.03	***	0.01	***		
Year2 (slope)	0.002	***	0.001	***		

Source: Own elaboration.

RJ = Rio de Janeiro; NOI = Niterói; SG = São Gonçalo; BF = Baixada Fluminense; LF = Leste Fluminense excluding the municipalities of Niterói and São Gonçalo; BIG = Baia da Ilha Grande; BL = Baixada Litorânea; CS = Centro-Sul; MP = Médio Paraíba; NOE = Noroeste; N = Norte; S = Serrana.

RR = Rate ratio; Adj = Adjusted; inter = intercept; Std. Dev. = Standard Deviation; P-v = P-value; P-value significance codes: *** : < 0.001; ** : < 0.01; * : < 0.05; • : < 0.10; NS : > 0.10

Note: We used Poisson multilevel modeling, with the following random effects: region (intercept), death year (slope), and the death year square term (slope). The response variables of crude and adjusted models were neonatal, postneonatal, and infant mortality. Fixed effects of the three adjusted models were region, death year, and death year square term. Also, we included an offset with the logarithm of the live births.

Discussion

The infant mortality rate in the capital of the state of Rio de Janeiro in 2017 was slightly lower than the rate in Brazil (11.22/1,000 vs. 13.4/1,000[17]), which can be considered high compared to developed countries. China, for example, experienced almost half of the infant mortality rate in Brazil in 2017[18].

Infant mortality data as for all Brazilian states from 1990 to 2015 also indicate falling rates. The decline has enabled the Country to meet the Millennium Development Goals targets[14]. The intra and inter-regional differences in infant mortality rates persist among certain Brazilian regions. Data from 2000 to 2016 confirm that the North and Northeast regions showed the highest infant mortality rates. The Northeast depicted the highest rates in 2000 (45/1,000), although decreasing more sharply than in other regions, and reaching in 2014 the same mortality levels as in the North region (18/1,000)[19]. The South is the region showing the lowest infant mortality rate since 2000, reaching 9/1,000 in 2016, and followed by the Southeast (10/1,000 in 2016). In 2016, the infant mortality rate was almost 50% lower in the South than in the North and Northeast regions[19].

On the other hand, disparities are also found within large regions. For example, in the North region (2006), Tocantins showed the lowest infant mortality rate (16/1,000), while Amapá depicted the highest one (23/1,000). In the Northeast region, Pernambuco experienced the lowest infant mortality rate (13/1,000), while Maranhão faced the worst ones (21/1,000). The South and Southeast regions showed the lowest disparities in infant mortality rates[19].

In general, the determinants of infant mortality can be subdivided into 1) distal determinants: demographic and socioeconomic characteristics; 2) intermediate determinants: health care and maternal characteristics; and 3) proximal determinants: characteristics of the newborn[20,21].

Socioeconomic condition is an important factor affecting disparities in infant mortality rates, especially deaths after the first month of life. Basic sanitation coverage, for example, affects the occurrence of diarrheal diseases, which, in its turn, exerts a significant impact on infant mortality. Specific interventions to reduce the regional differences can decrease socioeconomic inequities, improving sanitary conditions in communities and reducing infant mortality by diarrhea.

Urban areas are home to about 55% of the world's population[22]. In southeastern Brazil, where the state of Rio de Janeiro is located, about 93% of the population lives in urban areas[23]. This growing percentage of urbanity over the years is justified by the search for work in large cities and greater infrastructure. One of the challenges to be overcome in Brazil, as well as in other countries is housing, especially for the low-income population, given that the housing process is a consequence of a visible picture of social inequality. The occupation process of territories in urban areas occurs without prior planning, in areas unsuitable for housing, infringing several aspects such as 1) environmental issues, related to protected environmental spaces and the nature of risk to the environment and the occupants themselves; 2) legal, related to the prohibition of building construction in those locations; 3) socioeconomic, as these occupations are often associated with poverty and social exclusion[24].

The factors that possibly contributed to the high infant mortality rates found in the Baixada Fluminense in the present study can be related to socioeconomic factors, considering that this is a quite poor region of the state. A Brazilian study (2006-2008) found an association between socioeconomic indicators and the risk of infant death[25].

Neonatal mortality reduced in the state of Rio de Janeiro from 16.90 to 8.81 deaths per thousand live births over the period 1996 to 2020. These results indicate that the state of Rio de Janeiro is fulfilling the goal of reducing neonatal mortality to at least 12 per 1,000

live births, listed among the United Nations' Sustainable Development Goals. The state of Rio de Janeiro met this goal in 2004, when the neonatal mortality reached the rate of 11.80/1,000. Despite all, rates displayed for Rio de Janeiro are still high when compared to cities of developed countries like London and New York, where neonatal mortality rates hover around three or fewer deaths per thousand live births[26,27].

Neonatal mortality has been a growing public health concern in Brazil since the 1990s, when it became the main component of infant mortality due to the sharp reduction in post neonatal mortality. The neonatal mortality rate reflects the quality of prenatal care and delivery. Congenital syphilis can also affect neonatal mortality rates. During the study period, the percentage of neonatal deaths in the State, whose underlying cause was congenital syphilis, began to increase from 2008 onwards, ranging from 0.43% in 2008 to 3.14% in 2017. Comparing the total neonatal mortality rates in the State with what would be the corrected rates, excluding deaths from congenital syphilis, we observe that the temporal trend lines stop overlapping, especially from 2015 onwards. A spatial analysis study showed a reduction in neonatal mortality of all Brazilian regions from 1997 to 2012[28]. In 2015, infant deaths in Brazil represented about 90% of the total number of deaths under-5 years. The 0-7 days age group contributed to 41% of all under-5 years old deaths, followed by those of 28–364 days, 7–27 days, and 1–4 years old age groups[29]. The concentration of deaths during the first week of life is related to the quality of actions aimed at maternal health, e.g., prenatal care and childbirth assistance.

Prematurity and congenital anomalies are important causes of infant death in Brazil, although their rates have reduced since 1990. In 2015, infant mortality rates due to prematurity and congenital anomalies reached respectively 3.18/1,000 and 3.03/1,000[29]. Regarding diseases preventable by immunization, their reduction over time seems to have contributed to the reduction of infant deaths[29]. As to congenital syphilis, Brazil has not met the goal of eliminating the disease. The persistence of the epidemic results in significant neonatal and fetal mortality. This persistence has several causes, among them, inadequate prenatal care, e.g., less than six medical visits, and the recent temporary lack of the antibiotic benzathine penicillin.

A study conducted from 1974 to 2004 reinforces that the reduction in mortality in the first week of life was uninportant[30]. The factors stressed by the authors as connected to the neonatal component of infant mortality include both the improvement of technological resources required to deliver a high-risk baby and the largest primary health care offering[30].

High post neonatal mortality rates are related to external factors, like diarrheic diseases due to low basic sanitation coverage. Mostly, high rates reflect low levels of socioeconomic development and living conditions[1]. In Tokyo, for example, the post-neonatal mortality rate was around 1.5/1,000 in 2012[31]. Both Baixada Fluminense and São Gonçalo present some common structural problems that can justify the higher post neonatal mortality rates observed in the 2016-2020 period. Some of them are lack of job opportunities, poor basic sanitation, insufficient health and education networks, and higher hospitalization rate for diarrhea: 0.3/1,000 inhabitants in Baixada Fluminense and São Gonçalo vs. 0.1/1,000 inhabitants in Rio de Janeiro and Niterói[32].

The higher infant mortality rates in the Brazilian regions between 2015 and 2016 were influenced by the increase in the postnatal diarrhea-specific mortality coefficient in the North, Northeast, Southeast, and Midwest[15]. Results of a spatial correlation study indicated a positive relation between perinatal mortality and socioeconomic factors[33]. There is evidence of a reduction in mortality as the maternal education increase[34]. It is important to maintain continuous monitoring of the spatial distribution of the infant mortality components.

We detected a stabilization of the infant mortality rates in recent years. This pattern

seems to have also occurred in Brazil as a whole. A study spanning from 1990 to 2015 also showed a reduction of 67.6% in the Brazilian infant mortality rate[29]. However, the Brazilian Health Ministry reports an increase in 2016, which occurred also in Brazil as a whole as in each region, except for the South, where it kept decreasing. In 2017, compared to 2016, a fall was still observed in infant mortality in all regions, except for the South, where rates remained stable[17].

Data indicate that most infant deaths in the city of Rio de Janeiro occur in public health care (70%), which concentrates the most significant number of childbirth and birth service[3]. The expansion of the Family Health Strategy coverage was a factor that positively impacted the reduction of infant mortality, including access to primary care to the poorest populations. As a result, it made feasible to reduce malnutrition and to increase breastfeeding rates, both of which are important factors to reduce infant mortality rates[29]. Perhaps what is still missing is qualifying of the service.

In August 2011, the Brazilian Ministry of Health implemented a national program called 'Rede Cegonha' in the metropolitan regions of Rio de Janeiro so to structure and organize maternal and infant health care in Brazil. However, Rede Cegonha program still faces problems such as discoordination of services, fragmentation of actions, absence of bed guarantee in the maternity ward, difficulty in linking the pregnant woman to the maternity ward and in her transportation to the maternity ward.

The underreporting of live births and infant deaths is a limitation of this study. The heterogeneities of birth underreporting resulting from intra-regional inequalities in the units included in the study may have been hidden in the analysis process. However, in southeastern states, such as Rio de Janeiro, this problem shows a lower magnitude[29,30]. A study conducted in Northeast Brazil from 1980 to 2012 stressed the incompleteness of the death certificate's as for the cause of death, the underlying cause of death being the better determinant in 52% of deaths[13]. Another study suggests that underreporting is related to the fact that the municipality is a urban or rural one, as the rural one usually shows higher number of underreporting[35]. Ethnicity is another factor reported in the literature as related to underreporting. Non-whites infant deaths would run a greater chance of underreporting[35]. Since the literature emphasizes differences in infant mortality according to race in Brazil – higher infant mortality in non-whites[36] –, underreporting may be even greater in populations with a higher proportion of non-white individuals.

The mortality system is fed with information from death certificates. Training and encouraging services for the correct completion of death certificates have also contributed to data quality improvement[14, 37].

The Live Births Information System has been improving its coverage and quality in Brazil from 2000 to 2015[14,33,34]. Death surveillance plays a key role in informing preventable deaths. Actions for identification, investigation, analysis, and monitoring of deaths have been carried out to increase the number of notifications of births and deaths captured in Live Birth and Mortality Information Systems.

The general trends of infant mortality and its components suggest that the rates decreased from 1996 to 2020 in every region, although a recent stabilization of the rates was detected in the last years of the study. The results of this study indicate the need for constant monitoring of factors related to infant mortality components, especially those concerning the improvement of delivery care, seeking to qualify delivery care and birth.

Strategies aimed at reducing iatrogenic prematurity or intrapartum asphyxia due to interventions during childbirth can contribute to reduce neonatal mortality. The incentive for natural births can also contribute to reduce prematurity since the literature reinforces that the increase in prematurity rates is connected

to high rates of cesarean sections. In addition, it is important to carry on social policies already in place, such as income transfer programs aimed at the poorest population, maternal and child care policies, and improvement in children's living conditions and health. Income transfer programs, for example, promote the monitoring of pregnant women through prenatal care and of children under the age of seven. The program also has repercussions in reducing illiteracy and fertility rates, and the number of people with inadequate basic sanitation conditions.

Collaborators

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References

1. Brasil. Ministério da Saúde, Rede Interagencial de Informações para a Saúde. Indicadores básicos para a saúde no Brasil: conceitos e aplicações. 2. ed. Brasília, DF: OPAS; 2008.

2. Lansky S, Friche AAdL, Silva AAMd, et al. Pesquisa Nascer no Brasil: perfil da mortalidade neonatal e avaliação da assistência à gestante e ao recém-nascido. Cad. Saúde Pública. 2014; 30(supl1):S192-S207.

3. Rio de Janeiro. Secretaria Municipal de Saúde. Mortalidade infantil no MRJ Rio de Janeiro: Superintendência de Vigilância em Saúde; 2019. [accessed 2023 Jul 17]. Available in: http://www.rio.rj.gov.br/dlstatic/10112/7973075/4299725/MortalidadeInfantilnoMRJ.pdf.

4. Programa das Nações Unidas para o Desenvolvimento. Desenvolvimento Humano e IDH. [accessed 2023 Jul 17]. Available in: https://www.undp.org/pt/brazil/idh.

5. Instituto Brasileiro de Geografia e Estatística. Cidades e Estados. 2014. [accessed 2023 Jul 17]. Available in: http://www.ibge.gov.br/home/mapa_site/mapa_site.php#geociencias.

6. Xu J, Murphy SL, Kockanek KD, et al. Mortality in the United States, 2018. NCHS Data Brief. 2020; (355):1-8.

7. The Word Bank. Mortality rate, infant (per 1,000 live births) - Sub-Saharan Africa. 2020. [accessed 2020 Jan 20]. Available in: https://data.worldbank.org/indicator/SP.DYN.IMRT.IN?locations=ZG.

8. Ogbo FA, Ezeh OK, Awosemo AO, et al. Determinants of trends in neonatal, post-neonatal, infant, child and under-five mortalities in Tanzania from 2004 to 2016. BMC Public Health. 2019; 19(1):1243.

9. Kamal R, Hudman J, McDermott D. What do we know about infant mortality in the U.S. and comparable countries? Peterson-KFF Health System Tracker. 2019 out 18. [accessed 2023 Jul 17]. Available in: https://www.healthsystemtracker.org/chart-collection/infant-mortality-u-s-compare-countries/.

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10. Leal MDC, Szwarcwald CL, Almeida PVB, et al. Reproductive, maternal, neonatal and child health in the 30 years since the creation of the Unified Health System (SUS). Ciênc. saúde coletiva. 2018; 23(6):1915-28.

11. Brasil. Ministério da Saúde. Vigilância em Saúde no Brasil 2003-2019. Boletim Epidemiológico. 2019 [accessed 2023 Jul 17]. (n. especial):1-156. Available in: https://portalarquivos2.saude.gov.br/images/pdf/2019/setembro/25/boletim-especial-21ago19-web.pdf.

12. Saltarelli RMF, Prado RRD, Monteiro RA, et al. Trend in mortality from preventable causes in children: contributions to the evaluation of the performance of public health services in the Southeast Region of Brazil. Rev Bras Epidemiol. 2019; (22):e190020.

13. Oliveira CM, Bonfim CV, Guimarães MJB, et al. Mortalidade infantil: tendência temporal e contribuição da vigilância do óbito. Acta Paul Enferm. 2016; 29(3):282-90.

14. Brasil. Ministério da Saúde. Saúde Brasil 2017: Uma análise da situação de saúde e os desafios para o alcance dos Objetivos de Desenvolvimento Sustentável. Brasília, DF: MS; 2018. [accessed 2023 Jul 5]. Available in: http://bvsms.saude.gov.br/bvs/publicacoes/saude_brasil_2017_analise_situacao_saude_desafios_objetivos_desenvolvimento_sustetantavel.pdf.

15. Abrasco. Especial Abrasco sobre o aumento da mortalidade infantil e materna no Brasil. Rio de Janeiro: Abrasco; 2018. [accessed 2023 Jul 5]. Available in: https://www.abrasco.org.br/site/outras-noticias/institucional/especial-abrasco-sobre-o-aumento-da-mortalidade-infantil-e-materna-no-brasil/36777/.

16. Silva L. Baixada Fluminense como vazio demográfico? População e território no antigo município de Iguaçu (1890/1910). Rev. bras. estud. popul. 2017; 34(2):415-25.

17. Brasil. Ministério da Saúde. Saúde Brasil 2019 - Uma análise da situação de saúde com enfoque nas doenças imunopreveníveis e na imunização Brasília, DF: Ministério da Saúde; 2019. [accessed 2023 Jul 5]. Available in: https://portalarquivos2.saude.gov.br/images/pdf/2019/dezembro/05/Saude-Brasil-2019--imunizacao.pdf.

18. Embaixada China. Expectativa de vida dos chineses aumenta para 76,7 anos. [accessed 2023 Jul 5]. Available in: http://br.china-embassy.org/por/szxw/t1568569.htm.

19. Instituto Brasileiro de Geografia e Estatística. Taxa de mortalidade infantil. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística; 2020. [acesso em 2023 jul 5]. Disponível em: https://sidra.ibge.gov.br/Tabela/3834.

20. Jobim R, Aerts D. Mortalidade infantil evitável e fatores associados em Porto Alegre, Rio Grande do Sul, Brasil, 2000-2003. Cad. Saúde Pública. 2008; 24(1):179-187.

21. Lima S, Carvalho ML, Vasconcelos AG. Proposal for a hierarchical framework applied to investigation of risk factors for neonatal mortality. Cad. Saúde Pública. 2008; 24(8):1910-6.

22. United Nations Human Settlements Programme. World Cities Report 2022: Envisaging the future of cities. Nairobi: United Nations Human Settlements Programme; 2022. [accessed 2023 Jul 5]. Available in: https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf.

23. Instituto Brasileiro de Geografia e Estatística. PNAD - Pesquisa Nacional por Amostra de Domicílios 2015 Rio de Janeiro: IBGE; 2023. [accessed 2023 Jul 5]. Available in: https://www.ibge.gov.br/estatisticas/sociais/educacao/9127-pesquisa-nacional-por-amostra-de-domicilios.html.

24. Pavez CMP, Freitas MJCC, Dias VLN. "Favela" Territory (ies) and Socio-Environmental Conflicts: in the Arvoredo Community, Florianópolis-sc. Ambient. Soc. 2019; (22):e01692.

25. Ramalho WM, Sardinha LM, Rodrigues IP, et al. Inequalities in infant mortality among municipalities in Brazil according to the Family Development In-

dex, 2006-2008. Rev Panam. Salud. Publica. 2013; 33(3):205-12.

26. Trust for London. Infant mortality Infant mortality rate per 1,000 live births (2001-2020). [accessed 2023 Jul 5]. Available in: https://trustforlondon.org.uk/data/infant-mortality-over-time/.

27. New York. Department of Health. Table 45: Infant Deaths, Neonatal Deaths, Post Neonatal Deaths and Perinatal Mortality By Resident County New York State – 2015. New York: Department of Health; 2015. [accessed 2023 Jul 5]. Available in: https://www.health.ny.gov/statistics/vital_statistics/2015/table45.htm.

28. Rodrigues NCP, Monteiro DLM, Almeida AS, et al. Temporal and spatial evolution of maternal and neonatal mortality rates in Brazil, 1997–2012. J. Pediatr. (Rio J.). 2016; 92(6):567-573.

29. França EB, Passos VMA, Malta DC, et al. Cause-specific mortality for 249 causes in Brazil and states during 1990-2015: a systematic analysis for the global burden of disease study 2015. Populat. health metrics. 2017; 15(1):39.

30. Matos LN, Alves EB, Teixeira EMM, et al. Mortalidade de infantil no município do Rio de Janeiro. Esc. Anna Nery R Enferm. 2007; 11(2):283-8.

31. Tashiro A, Yoshida H, Okamoto E. Infant, neonatal, and postneonatal mortality trends in a disaster region and in Japan, 2002-2012: a multi-attribute compositional study. BMC Public Healt. 2019; 19(1):1085.

32. Intituto Brasileiro de Geografia e Estatística. IBGE Cidades Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística. 2020. [accessed 2023 Jul 5]. Available in: https://cidades.ibge.gov.br/.

33. Migoto MT, Oliveira RP, Andrade L, et al. Correlação espacial da mortalidade perinatal com condições sociais, econômicas e demográficas: estudo ecológico. R Saúde Públ Paraná. 2020; (3):75-85.

34. Martins EF, Rezende EM, Almeida MCdM, et al. Perinatal mortality and socio-spatial inequalities. Rev. Latino-Am. Enfermagem. 2013; 21(5):1062-70.

35. Gava C, Cardoso AM, Basta PC. Infant mortality by color or race from Rondônia, Brazilian Amazon. Rev Saude Publica. 2017; (51):35.

36. Birn AE. Child health in Latin America: historiographic perspectives and challenges. Hist Cienc Saude Mang. 2007; 14(3):677-708.

37. França EB, Lansky S, Rego MAS, et al. Principais causas da mortalidade na infância no Brasil, em 1990 e 2015: estimativas do estudo de Carga Global de Doença. Rev Bras. Epidemiol. 2017; (20):46-60.

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