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Fetal and infant mortality trends according to the avoidability of causes of death and maternal education

Tendência da mortalidade fetal e infantil segundo evitabilidade das causas de morte e escolaridade materna

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ABSTRACT: ***Objective:*** To estimate trends of fetal (FMR) and neonatal (NMR) mortality rates due to avoidable causes and maternal education in the city of Rio de Janeiro (2000–2018). ***Methods:*** Ecological time series study. Mortality and Live Birth Information System Data. The List of Avoidable Causes of Death Due to Interventions of the Brazilian Health System was used for neonatal deaths and an adaptation for fetal deaths, according to maternal education indicators (low <4 and high ≥12, years of study). Joinpoint regression models were used to estimate trends in FMR, based on one thousand births, and NMR, based on one thousand live births. ***Results:*** FMR decreased from 11.0 to 9.3% and NMR from 11.3 to 7.8% (2000/2018). In 2006, FMR (10.5%) exceeded NMR (9.0%), remaining higher. From 2000 to 2018, the annual decrease of FMR was 0.8% (2000 to 2018) and of NMR, 3.8% until 2007, decreasing to 1.1% by 2011; from then on, it remained stable. Avoidable causes, especially those reducible by adequate prenatal care, showed higher rates. Both FMR and NMR for low-education women were higher than those for the high-education level, the difference being much more pronounced for FMR, and at the end of the period: low- and high-education FMR were respectively 16.4 and 4.5% (2000) and 48.5 and 3.9% (2018), and for NMR, 18.2 and 6.7% (2000) and 28.4 and 5.0% (2018). ***Conclusion:*** The favorable trend of decreasing mortality was not observed for children of mothers with low education, revealing inequalities. The causes were mostly avoidable, being related to prenatal care and childbirth.

Keywords: Fetal mortality. Infant mortality. Time series studies. Underlying cause of death. Educational status. Health inequality monitoring.

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RESUMO: ***Objetivo:*** Estimar a tendência das taxas de mortalidade fetal (TMF) e neonatal (TMN) por causas evitáveis e escolaridade materna no município do Rio de Janeiro (RJ) (2000–2018). ***Métodos:*** Estudo ecológico de séries temporais. Dados do Sistemas de Informações sobre Mortalidade e Nascidos Vivos. Utilizou-se a Lista Brasileira de Evitabilidade para óbitos neonatais, e sua adaptação para óbitos fetais, segundo indicadores de escolaridade materna (baixa < 4 e alta ≥ 12 anos de estudo). Utilizaram-se modelos de regressão Joinpoint para estimar tendência da TMF por mil nascimentos e TMN por mil nascidos vivos. ***Resultados:*** A TMF passou de 11,0 para 9,3‰, e a TMN de 11,3 para 7,8‰ (2000–2018). Em 2006, a TMF (10,5‰) ultrapassou a TMN (9,0‰), mantendo-se superior. Entre 2000 e 2018, o decréscimo anual da TMF foi de 0,8% (2000 a 2018), e o da TMN de 3,8% até 2007, desacelerando para 1,1% até 2011, seguindo com estabilidade. Causas evitáveis, principalmente aquelas reduzíveis por atenção à gestação, apresentaram taxas mais elevadas. Tanto a TMF como a TMN de mulheres com baixa escolaridade foram superiores às de alta, bem mais acentuada a diferença para TMF e no final do período: TMF de baixa e alta escolaridade foram, respectivamente, 16,4 e 4,5‰ (2000) e 48,5 e 3,9‰ (2018); para TMN, 18,2 e 6,7‰ (2000) e 28,4 e 5,0‰ (2018). ***Conclusão:*** A tendência favorável de decréscimo da mortalidade não foi observada para filhos de mães com baixa escolaridade, revelando desigualdades. As causas foram majoritariamente evitáveis, relacionadas à assistência pré-natal e no parto.

Palavras-chave: Mortalidade fetal. Mortalidade infantil. Estudos de séries temporais. Causa básica de morte. Escolaridade. Monitoramento das desigualdades em saúde.

INTRODUCTION

Worldwide, there was a reduction in neonatal mortality rate (NMR), from 37 to 18 deaths per thousand live births (LB) between 1990 and 2018[1].

In Brazil, between 1990 and 2015, the decrease was 59%, going from 23.1 to 9.5 neonatal deaths per thousand LB[2]. In 2016, there was a slight increase, and in 2017, a decrease of 1.7% compared to the previous year[3]. Inequality in the decline between regions was dependent on the initial magnitude of NMR[3]. In the state of Rio de Janeiro and in the capital, the rates were lower, respectively 13.6 and 11.2 in 2000 and 8.4 and 7.8 in 2018 per thousand LB, resulting in smaller decreases (38 and 30.3%)[4].

Parallel to neonatal deaths, fetal deaths reflect maternal morbidities and problems with prenatal care and childbirth. Until recently, these deaths were considered invisible, receiving little attention from researchers and managers[5-7]. The fact that neonatal and fetal deaths share maternal causes justifies the study of both conditions to support planning, management and evaluation of health policies and measures for women and newborns[5,6]. In the case of fetal deaths, studies have identified the need for specific interventions in prenatal and childbirth care[5].

The most recent global estimate for fetal deaths was 2.6 million in 2015, corresponding to a fetal mortality rate (FMR) of 18.5 deaths per thousand births[6]. It is worth recalling that this rate, for international comparison, only includes stillbirths with a weight ≥1000 g or gestational age ≥28 weeks. Blencowe et al.[6] identified NMR and the prevalence

of low weight, besides geographical location, as predictors of fetal mortality. The gross domestic product, the average number of years of maternal education and the number of prenatal visits were protective. Because of the relevance of fetal deaths and their slower reduction compared to neonatal deaths, worldwide initiatives have started to include their prevention[6].

National estimates of FMR time trends from 2000 to 2016 showed stationary values (around 5 per thousand births) and large regional differences[8]. Stability was reproduced among the causes of Chapter XVI, except for the Northeast. Fetal deaths predominated between the 28th and 36th weeks of gestation, with an increasing trend, except in the South[8].

Since 2000, infant deaths have been mostly close to birth, and their main causes have been related to prenatal, childbirth and newborn care[2]. Intersectoral social policies, such as wealth distribution and Bolsa Família (family conditional cash transfer program), maternal and child health policies, such as the National Program for the Humanization of Delivery and Birth and the Kangaroo Method, increased maternal education, reduction in fertility and universalized assistance with the Unified Health System (SUS) have contributed to the decrease in infant mortality and reduction of inequalities[2]. It is noteworthy, however, that the causes of infant and neonatal death are mostly avoidable by the effective action of health services[3,9].

Between 2013 and 2016, in Brazil, 127,330 fetal deaths (31,833 deaths/year) were registered, a total higher than that of neonatal deaths, i.e., 105,106 (26,276/year)[10]. The most common underlying causes were fetal death of unspecified cause (21.5%) and unspecified intrauterine hypoxia (15%), showing gaps in knowledge[10]. Of the total, 17.1% had a weight ≥2500 g and occurrence at term. The occurrence of death in fetuses and newborns weighing ≥2500 g and/or at term warns of a potentially avoidable death[3,10]. In the case of fetal deaths, it can still suggest problems in recording vital statistics[10].

Maternal education has been adopted as a measure of socioeconomic position[11] to assess neonatal mortality in low-, medium-[12] and high-income countries[13]. It was able to reveal inequalities in fetal, neonatal and post-neonatal mortality in Denmark, in the first decade of the 21st century[13]. Similar results were described in the birth cohorts of Pelotas (RS), Brazil (1993 to 2004), and Avon, United Kingdom (1991)[14]. Blencowe et al.[6] showed an inverse association between the average years of study and the FMR. The use of maternal education as an indicator of the family's socioeconomic status is recommended in Brazil, for analysis of infant and fetal mortality, by the Ministry of Health[15]. Studies of temporal trends in infant[16], neonatal[17] and fetal[18] mortality have also used maternal education as a socioeconomic indicator. In addition to being corroborated in the literature, it is information present in information systems, allowing population-based analyses.

The present study estimated the trend of FMR and NMR according to avoidable causes of death and maternal education in the city of Rio de Janeiro (RJ), from 2000 to 2018.

METHODS

An ecological study of the historical series of the annual fetal and neonatal mortality rate was conducted, considering the avoidability of the causes of death and maternal education, in RJ from 2000 to 2018.

The sources of mortality and LB data were respectively the Mortality and Live Birth Information Systems of the SUS Department of Informatics. Neonatal deaths and live births were referred to using the data tabulator - Tabnet do Ministério da Saúde[19]. Fetal deaths were obtained from the databases available for download[20] and analyzed by the statistical program Stata version 14.0.

Fetal deaths correspond to those with gestational age ≥22 weeks, and neonatal deaths, from 0 to the 27th complete day of life, according to the International Statistical Classification of Diseases and Related Health Problems (ICD), tenth edition[21].

Deaths were classified according to the List of Avoidable Causes of Death Due to Interventions of the Brazilian Health System (LBE) [22]. The classification groups the causes of death into three groups: avoidable deaths; ill-defined deaths; other causes (not clearly avoidable). The group of avoidable causes is composed of six subgroups, considering the type of intervention:

1.1) Reducible by immunoprevention;
1.2) Reducible by adequate care for woman in pregnancy and childbirth and for fetus and newborn:
    1.2.1) Reducible by adequate prenatal care;
    1.2.2) Reducible by adequate intrapartum care;
    1.2.3) Reducible by adequate care of the fetus and newborn;
1.1) Reducible by adequate diagnosis and treatment;
1.2) Reducible by health promotion measures linked to adequate healthcare measures.

The LBE was adapted for fetal deaths on the basis of the study of Vieira et al.[23] and the proposal of Saúde Brasil 2018[10]. Vieira et al.[23] proposed two changes:

- Allocate fetal deaths whose cause was maternal diabetes (ICD: P70.0 and P70.1) of the subgroup of causes that can be reducible by adequate care of the fetus and newborn to those that can be reducible by adequate prenatal care;
- Consider the code P20.9, which deals with hypoxia without specifying the time of occurrence, ill-defined cause[23].

The document from the Ministry of Health[10] argues that some ICD codes applied to fetal deaths generate inconsistency as they are exclusive to newborns, such as P22, P24, P51, P54, P58, P59, P71 to P74 (already mentioned above), P80, P81, P90 to P92 and P94[10].

We determined the annual fetal deaths per thousand births (the sum of the number of fetal deaths ≥22 weeks of gestation and those with missing information of gestational age divided by the sum of the number of LB, fetal deaths ≥22 weeks and those with missing

information of gestational age)[15] and neonatal deaths per thousand LB[15] (the sum of the number of neonatal deaths divided by the sum of the number of LB), according to maternal education and the group of LBE and adapted LBE.

Relative annual frequencies of deaths were described according to the avoidability group, and for the subgroup of avoidable causes, the main causes were described (ICD codes).

Using maternal education as a measure of socioeconomic status[13], specific mortality rates were analyzed, considering low and high education, respectively <4 and ≥12 years of study. Due to the incompleteness of the education variable, 25 and 18%, respectively, for fetal and neonatal deaths, a sensitivity analysis of mortality rates was carried out, allocating all records with missing information for low education and, later, for high education.

For trend analysis, the Joinpoint regression model was used, which fits a series of lines and their joinpoints on a logarithmic scale to demonstrate annual trends. We used the Monte Carlo Permutation Method to test for significance. The direction and magnitude of the estimated trend are represented by the annual percentage variation (APV), with a level of statistical significance of 0.05 being considered. Models with and without autocorrelation term (AC) were evaluated, and the term of AC was maintained in the models in which the APV changed by more than 0.2%. Joinpoint Regression software was used (https://surveillance.cancer.gov/joinpoint//). The trends presented in graphical form were better visualized on the logarithmic scale, allowing to observe the percentage distance between two points.

The present study, addressing RJ, is an integral part of the Study on Health Indicators for Women and Children in the Health Regions of the state of Rio de Janeiro, approved by the Research Ethics Committee of the Faculty of Medicine of Universidade Federal Fluminense (Process No. 4.091.556).

RESULTS

Totals of 15,845 fetal deaths and 14,660 neonatal deaths in RJ were analyzed, of which 23% occurred at term, and for birth weight, 25% of fetuses and 20% of neonates weighed ≥2500 g.

FMR and NMR showed a downward trend from 2000 to 2018: FMR went from 11.1 to 9.3 and NMR from 11.3 to 7.8 (Table 1). Fetal mortality showed an annual reduction of 0.8% for the entire period analyzed, and neonatal mortality showed a joinpoint, indicative of a change in trend in 2007: from 2000 to 2007, the annual decline was more pronounced, approximately 4%, compared to the subsequent period, about 1%, until 2018. Due to the difference in the intensity and duration of the reduction, FMR surpassed NMR as of 2006.

The magnitude and trend of the rates were mainly due to the behavior of deaths classified as avoidable (Table 1). Fetal mortality from avoidable causes showed two joinpoints (2002 and 2011) with a change in the direction of the trend, with only the initial decline (from 2000 to 2002) and the subsequent rise (from 2002 to 2011) being statistically significant. The joinpoint for the total and avoidable NMRs occurred in the same year, 2007.

Table 1. Annual percentage variation (APV), with 95% confidence interval (95%CI), for total fetal and neonatal mortality rates (MR) according to groups of avoidable causes and maternal education, in the city of Rio de Janeiro, 2000–2018.

Mortality rates	Periods of trends	MR**		Estimates			
		Initial	Final	APV	95%CI		AC
Total fetal	2000–2018*	11.1	9.3	-0.8	-1.2	-0.4	-
Avoidable fetal	2000–2002*	9.1	4	-34.3	-45.5	-20.8	-0.5
	2002–2011*	4	6	4.6	3	6.3	
	2011–2018	6	6.2	0	-1.8	1.9	
Ill-defined fetal	2000–2002*	1.4	5.6	95.8	26.2	203.8	-0.1
	2002–2007	5.6	4.5	-3.8	-11.3	4.3	
	2007–2011	4.5	2.6	-12.4	-25.6	3.1	
	2011–2018	2.6	2.4	-2.2	-6.9	2.8	
Other fetal	2000–2018*	0.4	0.7	3.7	2.5	4.9	-
Fetal — low education	2000–2005	16.4	15.1	2.4	-5.8	11.2	-0.4
	2005–2015*	15.1	67.1	13.9	10.1	17.8	
	2015–2018	67.1	48.7	-9.4	-30.2	17.6	
Fetal — high education	2000–2018	4.5	3.9	0.4	-0.4	1.3	-0.5
Total neonatal	2000–2007*	11.3	8.2	-3.8	-5.2	-2.3	-
	2007–2018*	8.2	7.8	-1.1	-2	-0.3	
Avoidable neonatal	2000–2007*	9.0	6.1	-4.1	-5.6	-2.6	-0.3
	2007–2018*	6.1	6.0	-1	-1.8	-0.1	
Ill-defined neonatal	2000–2013*	0.3	0.1	-9.9	-12	-7.7	-0.5
	2013–2016	0.1	0.1	21.2	-53.8	217.6	
	2016–2018	0.1	0	-48.7	-88.4	126.7	
Other neonatal	2000–2004*	2.0	3.0	7.6	2.9	12.4	-0.3
	2004–2007	3.0	1.9	-10.6	-26.2	8.4	
	2007–2018	1.9	1.8	-0.5	-1.5	0.5	
Neonatal— low education	2000–2009	18.2	18.2	0.5	-1.2	2.2	-0.4
	2009–2015*	18.2	34.6	10.9	5.1	17.0	
	2015–2018	34.6	28.4	-6.3	-21.3	11.7	
Neonatal — high education	2000–2009*	6.7	3.9	-4.4	-7.4	-1.3	-0.2
	2009–2018	3.9	5.0	2.0	-1.3	5.3	

AC: autocorrelation; maternal education (years of study): low (<4) and high (≥12); *p < 0.05; ** fetal mortality per thousand births and neonatal mortality per thousand live births.

Fetal and neonatal mortality due to ill-defined causes had respectively three and two joinpoints that did not coincide (Table 1). From 2000 to 2002, there was a significant annual increase in FMRs due to ill-defined causes. Starting in 2002, the first joinpoint in the time series, the trend was decreasing. For neonatal mortality, only in the period from 2013 to 2016 was there a tendency for the annual rate to increase. In the preceding and subsequent periods, there was a decrease. There was a tendency for increased fetal mortality from other causes from 2000 to 2018 and, for neonatal mortality, only from 2000 to 2004.

Among the fetal deaths due to avoidable causes, the predominant subgroups were reducible by adequate prenatal care and reducible by adequate intrapartum care (Table 2). In the first two years, the main subgroup of avoidable causes was reducible by adequate intrapartum care, which moved to second place since then. For neonatal deaths, in all years, the main subgroup was reducible by adequate prenatal care, followed by reducible by adequate care of the fetus and newborn, and reducible by adequate intrapartum care (Table 2).

In the subgroup reducible by adequate prenatal care, the main causes of neonatal death were hypertensive maternal disorders (ICD-P00), followed by respiratory distress in newborns (ICD-P22), from 2000 to 2010, which afterward changed positions in the ranking. For fetal deaths, the two main causes of death were hypertensive diseases and complications of the placenta until 2004. Deaths due to early congenital syphilis have come to occupy the second leading cause of fetal deaths since 2005, except in 2007, when they were overtaken by other and unspecified morphological and functional abnormalities of the placenta (ICD-P02.2) and started to occupy the third position.

The three main causes of fetal deaths in the subgroup reducible by adequate intrapartum care were intrauterine hypoxia before and during labor (ICD-P20.0 and P02.1) and the fetus or newborn affected by umbilical cord compression (ICD- P02.5), and for neonatal deaths (ICD-P02, P21 and neonatal aspiration syndrome - P24) with variations in ranking in the years analyzed.

The codes of the subgroup reducible by adequate care of the fetus and newborn (1.2.3) was second among neonatal deaths, highlighting perinatal infection, for which the newborn's unspecified bacterial sepsis (ICD-P36.9) was mostly the case. For fetal deaths, this subgroup (except for some codes reallocated to the subgroup reducible by adequate prenatal care) was not applied.

Only three cases of pertussis, one of congenital rubella in neonates and two in fetuses made up the immunoprevention group (1.1).

Groups 1.3 and 1.4 of the LBE, related to adequate diagnostic and treatment actions and health promotion measures, respectively, did not apply to fetal deaths. For neonatal deaths, these two subgroups contributed up to about 3% of the total avoidable causes (Table 2).

The fetal and neonatal specific mortality rates according to maternal education are shown in Figure 1. There were higher mortality rates for children of mothers with low education when compared to those of mothers with high education, which is much more pronounced for fetal deaths.

Additionally, the temporal trend was different: fetal mortality for low education had two joinpoints (2005 and 2015), with a significant increasing trend of 13.9% per year between 2005 and 2015. For high education, there was no joinpoint, and no significant trend was detected. Neonatal mortality showed joinpoints and a significant increasing trend for low education (2009 to 2015), with an annual increase of 10.9%. For high education, there was only one joinpoint, with a significant decline in NMR (4.4% per year) between 2000 and

Table 2. Causes of avoidable fetal and neonatal deaths in the city of Rio de Janeiro. 2000 to 2018.

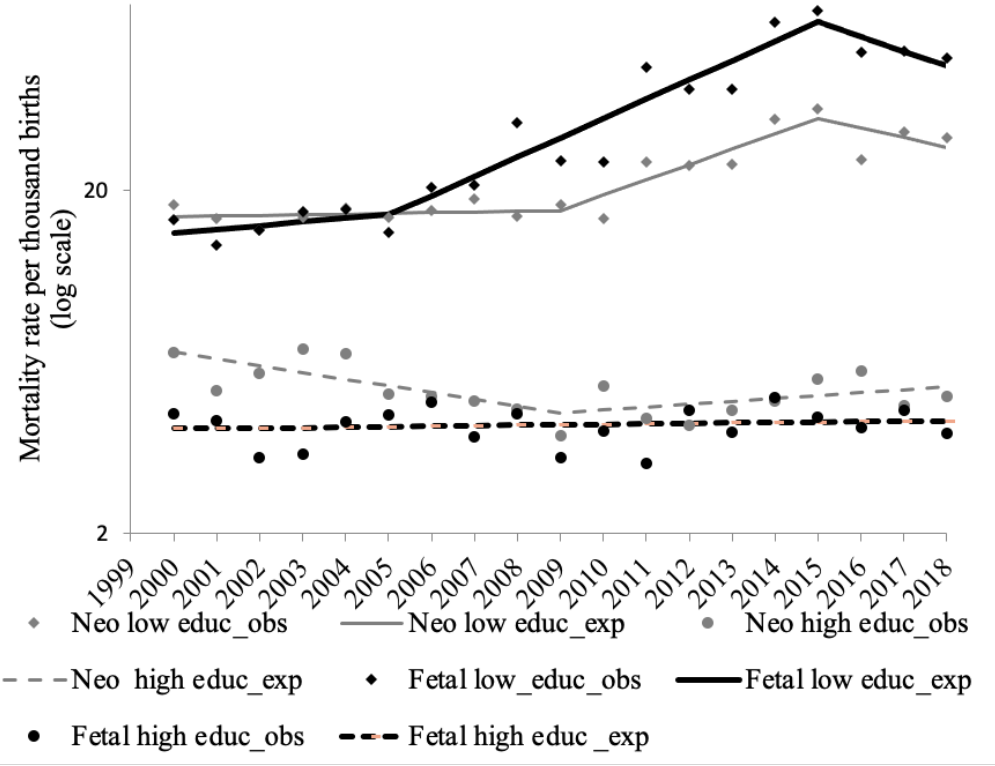
Year	Fetal*				Neonatal**						
	1.1	1.2.1	1.2.2	total	1.1	1.2.1	1.2.2	1.2.3	1.3	1.4	Total
	%	%	%	n	%	%	%	%	%	%	N
2000	0.1	44.2	55.7	910	0.0	46.9	17.1	33.9	1.7	0.5	885
2001	0.0	39.4	60.6	568	0.0	43.1	16.7	38.8	0.9	0.4	737
2002	0.0	54.3	45.7	348	0.0	51.5	14.8	31.5	1.5	0.7	718
2003	0.0	55.7	44.3	357	0.0	43.2	16.5	38.1	1.8	0.4	683
2004	0.0	69.4	30.6	445	0.0	51.4	14.0	33.8	0.7	0.2	615
2005	0.0	70.0	30.0	343	0.0	50.9	12.8	34.2	1.2	0.8	593
2006	0.0	75.6	24.4	381	0.0	51.7	14.4	31.8	1.0	1.0	578
2007	0.0	66.3	33.7	406	0.0	52.5	20.1	26.0	1.0	0.4	507
2008	0.0	69.3	30.7	440	0.0	53.0	17.8	27.7	0.6	0.9	534
2009	0.0	68.8	31.2	443	0.0	57.2	16.6	25.3	0.0	0.8	589
2010	0.0	78.1	21.9	484	0.2	59.4	16.1	23.0	0.6	0.8	527
2011	0.2	73.4	26.4	522	0.0	62.2	16.2	20.1	1.4	0.0	487
2012	0.0	80.9	19.1	560	0.5	63.3	14.1	19.0	1.5	1.6	547
2013	0.0	81.6	18.4	522	0.0	62.2	13.1	23.3	1.2	0.2	571
2014	0.0	74.8	25.2	532	0.0	59.8	14.5	24.9	0.6	0.2	502
2015	0.0	74.9	25.1	529	0.0	56.9	15.9	26.5	0.7	0.0	554
2016	0.0	75.2	24.8	491	0.0	58.7	12.7	26.1	0.8	1.7	521
2017	0.0	75.8	24.2	517	0.0	57.2	16.8	23.1	1.3	1.7	477
2018	0.0	76.2	23.8	513	0.0	59.7	18.2	21.1	0.4	0.6	494

*Brazilian List of Causes of Avoidable Deaths adapted for fetal deaths; ** List of Avoidable Causes of Death Due to Interventions of the Brazilian Health System (0–4 years); 1.1 Reducible by immunoprevention; 1.2.1 Reducible by adequate prenatal care; 1.2.2 Reducible by adequate intrapartum care; 1.2.3) Reducible by adequate care of the fetus and newborn; 1.3 Reducible by adequate diagnosis and treatment; 1.4 Reducible by health promotion measures linked to adequate healthcare measures.
Source: MS/SVS/DASIS — Information Systems on Mortality and Live Births.

2009, followed by stability (Table 1 and Figure 1). In the sensitivity analysis, the rates only showed a different behavior for high education: for NMR, the declining trend became significant in both periods (APV = -9% up to 2005 and APV = -1.9% in the subsequent period, with AC = -0.4), and for FMR, the trend started to show a decline and significance (APV = -2.8 from 2000 to 2018, with AC = -0.4).

DISCUSSION

We showed a favorable temporal evolution in the reduction of both neonatal and fetal mortality in RJ from 2000 to 2018, albeit slower for FMR. When analyzed according to maternal education, in addition to the inverse relationship with the number of years of study, both fetal and neonatal rates were high and rising among women with low education, revealing inequalities and supporting our study's premise. The sensitivity analysis confirmed the inequalities. Only in the situation where all records with



Maternal education (years of study): low <4 and high ≥12. Values observed (obs) and values expected (exp).
Source: MS/SVS/DASIS — Information Systems on Mortality and Live Births.

Figure 1. Rates of fetal mortality per thousand births and neonatal mortality per thousand live births according to maternal education. Rio de Janeiro. 2000–2018.

missing information were, in reality, high education, would there be a trend in decline of FMR. However, it seems unlikely, because missing information on maternal education is exactly those related to underprivileged people and distant from health services[24]. As for the upward trend in this range of education, it was confirmed for neonatal death, as had already been described in the state of Rio de Janeiro from 2004 to 2010[17], and found here even more so for the case of fetal deaths.

Considering studies in middle- and high-income countries, it is concluded that FMR may still undergo further reductions. In 2014, Croatia achieved an FMR of 3.8/thousand births[25], and Argentina 6.6/thousand births[26]. Australia[27] and the United States[28], even with a 20-week cut-off point for fetal death, found rates of 7 per thousand in 2015 and 5.7 per thousand in 2017, respectively, both with a decreasing trend. In these last two countries, term fetal mortality accounted for between 8 and 15%[27,28], while in RJ the value exceeded 20%.

As reported for the city and the state of São Paulo[29], there was a transition between fetal and neonatal mortality. From 2000 to 2005, NMR was greater than FMR in RJ. However, as of 2006, this relationship was reversed, and FMR remained higher until 2018.

When applying the adapted LBE for fetal deaths, a high percentage stood out in the category of ill-defined, reaching half of the deaths in some years. This is explained by the diagnosis of unspecified intrauterine hypoxia (P20.9), one of the most frequent causes reports in the death certificate of the fetuses. As the investigation of deaths is improved, this percentage tends to decrease[30], revealing the real cause and confirming that this is a GC[31]. Among the avoidable causes, those reducible by adequate prenatal care stood out, especially hypertensive diseases and congenital syphilis, which reinforces the importance of prenatal care, especially for high-risk women[7,32,33]. Studies in RJ in the last decade have shown low percentages of adequate prenatal care and inequalities in access and adequacy[34,35], in addition to failures in the management of hypertension[36]. There has also been difficulty in controlling congenital syphilis, evident in high rates of incidence and deaths, and failures in prenatal care are among the main factors for the worsening of the condition in RJ[37]. Certainly, the inequalities that permeate prenatal care have an impact on the negative outcome of pregnancy. About 80% of fetal deaths occurred in public hospitals in RJ, suggesting the most unfavorable socioeconomic profile of these women[30].

As for neonatal mortality, even with a reduction in the period studied, the NMR of 7.8 was higher than that found in other places in Brazil, such as Florianópolis[38], which reached 5.4 from 2012 to 2014, and Londrina[39], 7.5 between 2000 and 2013.

The pattern of avoidability was similar to that of fetal deaths, with a predominance of conditions that could be reduced by adequate care for women in pregnancy. Studies on the effectiveness of prenatal care in reducing neonatal mortality are corroborated[32,40], and conversely, inadequate prenatal care can increase the risk of neonatal death[33,41]. The second most frequent group of preventable causes, care for the newborn, was highlighted by unspecified neonatal septicemia. This diagnosis should be considered as a basic cause in neonates, in line with the discussion in older children and adults, in which the GC is considered[42].

Approximately 80% of these deaths occurred in preterm neonates and weighing less than 2,000 g (data not shown in the tables). Probably some maternal cause triggered the process of prematurity and low weight, which increases the risk of infection. The diagnosis of sepsis, although clinically relevant[39], obscures the investigation of maternal causes and the clarity in the necessary interventions.

As limitations of this work, we point out those inherent to the use of information systems, emphasizing the high percentage of missing sociodemographic information, which makes it difficult to further analyze inequalities. The absence of Death Verification Services in RJ and the flaws in the information in medical records contribute to greater inaccuracy in the certification of causes of death, making it difficult to target preventive measures[43].

As a strength of the study, the use of population bases and the temporal analysis stand out, which enhanced the understanding of the phenomenon. Although limited by the quality of the data, the databases of the Information Systems on Mortality and Live Births are universal and allow, with low cost and relative speed, the monitoring, and study of small and large population groups. The adaptation of LBE to fetal deaths proved to be adequate and necessary. The use of maternal education indicators as a proxy for inequalities revealed differences in magnitude and trend in mortality. Time trend analyses are crucial to identify patterns and changes in indicators and to associate them with health events or interventions. The choice for the joinpoint model is supported by national and international studies on infant mortality[17,44,45].

Neonatal and fetal deaths decreased in RJ, however insufficiently and still unevenly. In the period from 2010 to 2019, data from the Municipal Health Department[46] showed a reduction in the percentage of adolescent mothers, an increase in prenatal coverage, and stability in the percentage of low birth weight. These indicators are consistent with the reduction of neonatal and fetal mortality in the city.

Observing the transition of FMR and NMR, considering the slower decline in FMR and the high percentages of term fetuses with weight ≥2500 g, it is necessary to direct more efforts to reduce fetal mortality in the city studied. It is necessary to invest in prenatal care and childbirth so that women and their children can have favorable outcomes in this life cycle. As for information and research, it is necessary to improve the quality of the data, to guarantee adequate help in the development of public policies and decision-making.

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