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Revista Brasileira de Epidemiologia

https://doi.org/10.1590/1980-549720220038

ORIGINAL ARTICLE

Age-specific neonatal mortality and associated factors in the 2021 state of Rio de Janeiro (Brazil) birth cohort

Mortalidade neonatal específica por idade e fatores associados na coorte de nascidos vivos em 2021, no estado do Rio de Janeiro, Brasil

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ABSTRACT

Objective: To analyze the causes of age-specific neonatal deaths and death-associated factors in the 2021 state of Rio de Janeiro birth cohort. **Methods:** Retrospective cohort of live births (LB) followed up to 27 days of delivery (<24hs, 1–6 and 7–27 days). Data obtained from the Information Systems on Live Births (2021) and Mortality (2021/2022). We described the distributions of maternal and newborn characteristics and causes of death. We used multinomial regression models with hierarchical levels of determination of neonatal death. **Results:** Of the 179,837 LB, 274 died within 24 hours, 447 within 1-6 days and 324 within 7-27 days. The neonatal mortality rate was 5.8‰ LB (CI 95%: 5.5–6.2). Neonatal survivors and deaths were heterogeneous according to the analyzed characteristics, except for the reproductive history (p<0,05). 78% of causes of death were avoidable. Causes reducible by adequate care for pregnant women (<24 hours and 1-6 days) and newborns (7-27 days) predominated. Low schooling showed a significant association for deaths between 7-27 days ($OR_{ajusted}$=1.3); mixed race, for deaths between 1-6 days ($OR_{ajusted}$=1.3), and black color for both age groups (1-6 days: $OR_{ajusted}$=1.5 and 7-27 days: $OR_{ajusted}$=1.8). Health care and biological factors of LB (intermediate and proximal levels) remained strongly associated with neonatal death, regardless of age. **Conclusion:** Causes of death, factors associated with neonatal death, and strength of association differed according to death-specific age. Preventive actions for neonatal death should consider sociodemographic vulnerabilities and intensify adequate prenatal and perinatal care.

Keywords: Birth cohort. Neonatal mortality. Early neonatal mortality. Cause of death. Sociodemographic factors. Prenatal care.

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CONFLICT OF INTERESTS: nothing to declare.

HOW TO CITE THIS ARTICLE: Kale PL, Fonseca SC. Age-specific neonatal mortality and associated factors in the 2021 live birth cohort in the state of Rio de Janeiro, Brazil. Rev Bras Epidemiol. 2022; 25:e220038. https://doi.org/10.1590/1980-549720220038

Received on: 07/21/2022
Reviewed on: 09/19/2022
Accepted on: 09/22/2022

INTRODUCTION

The first month of life is the most vulnerable period for a child. In 2020, in the world, almost half of the deaths of children occurred in the neonatal period — the first 27 full days[1]. In Brazil, the neonatal mortality rate (NMR) dropped from 25.0 (1990) to 9.0 per thousand live births (LB) in 2020, an annual reduction of 3.6%[1] — less intense than for total mortality in childhood, 4.9%[1]. Of the total neonatal deaths (ND) in the country, 75% are early ones[2].

Regarding the trend of neonatal mortality in Brazil, the NMR was 7.9/1,000 LB in the Southeast Region in 2017, and the highest NMR in the region was in the state of Rio de Janeiro (RJ), 8.6/1,000 LB. NMR's trend in the state was downward, with an annual reduction rate of 1.6%[3].

Among infant deaths, the highest risk of death occurs on the first day of life[4]. About 2/3 of ND occur on the first day, and about 60% occur with up to three days of life in developing countries[5]. In Brazilian states, including Rio de Janeiro, mortality within 24 hours of delivery concentrated 1/5 of infant deaths from 2010 to 2015[4].

The causes of neonatal mortality in the country, especially in the first week of life, are related to prenatal care, childbirth, and newborn care, and are considered, for the most part, to be avoidable[4,6,7]. Causes not clearly avoidable, such as congenital anomalies, showed growth in both the proportion of total deaths and the cause-specific mortality rate from 2007 to 2017[3].

As for the factors associated with ND, a meta-analysis of Brazilian studies identified variables of sociodemographic aspects (age ≥35 years, absence of a partner), assistance (inadequate prenatal care, maternal morbidity, cesarean delivery), and related to the newborn (low weight, prematurity, asphyxia, and congenital malformation)[8]. Other studies corroborate these factors[9-14] and appended maternal education[9,14] and fetal presentation at delivery[12].

Most studies analyze the factors associated with total ND[9,10,12,14] either by early and late components[13], on the first day[4,15] or up to the first day, and from one to 27 days[16], without considering all these moments of occurrence and the potential age-specific differentiated behavior.

This study analyzed the magnitude of ND, causes of death and associated factors, by age-specific, in the 2021 state of RJ birth cohort.

METHODS

It is a retrospective 2021 state of Rio de Janeiro (Brazil) birth cohort. The follow-up period is from birth to 27 completed days of life. The outcome is age-specific neonatal death (<24 hours, one to six days, seven to 27 days) occurring in 2021 and 2022.

The data sources were the Information Systems on Live Births (*Sistema de Informações sobre Nascidos Vivos* – SINASC) and Mortality (*Sistema de Informações sobre Mortalidade* – SIM). Data were obtained from the Health Department of the state of Rio de Janeiro without nominal and residential identification.

Initially, the ND of newborns in 2021 were selected, which took place from January 1st, 2021, to January 27th, 2022. Subsequently, the deterministic linkage of the bases was performed (SINASC — 2021: 189,945 LB; and SIM — 2021 and 2022: ND=1,627) using the Statement of Live Birth (SLB) number as a linkage key. Eligibility criteria were birth weight ≥500 g, gestational age ≥22 weeks, and singleton pregnancy. Records with inconsistency between weight and gestational age were excluded[12]. The study population totaled 179,837 LB, of which 1,045 ND.

SLB variables analyzed were:

1. Maternal: age range (10–19/20–34/≥35 years), color (white/black/brown), and education (0–3/4–11/≥12, and <8/≥8 years).
2. Reproductive and care (pregnancy/delivery): number of dead/aborted children (none/≥1); number of children born alive (none/1–3/≥4); parity (number of previous deliveries: zero–primiparous/≥1–multiparous), cephalic presentation (yes/no); type of delivery (vaginal/cesarean). Adequacy of access to prenatal care: none (zero visit), inadequate (month of prenatal care onset >3, or ≤3 and number of visits <3), intermediate (month of prenatal care onset ≤3 and number of visits from 3 to 5), adequate (month of prenatal care onset ≤3 and number of visits=6) and more than adequate (month of prenatal care onset ≤3 and number of visits ≥7)[17] — was represented by the dichotomous variable prenatal inadequacy (yes — the first three categories/ no — the last two categories).
3. Newborn: gender (female/male), weight (<1,500 g/1,500–2,499 g/3,000–3,999 g/≥4,000 g), gestational age (<32/32–36/37–41/≥42 s), Apgar at 5th minute (<7/≥7).

Deaths were described according to investigation and the underlying causes of death (10th Revision of the International Classification of Diseases — ICD-10[18]) and preventability (Brazilian List of Avoidable Causes of Death/*Lista Brasileira de Causas de Morte Evitáveis* — LBE <5 years[19]). To describe the mention of COVID-19 (any line of the Death Certificate — DC, Part I or Part II), the recommendation of the Ministry of Health[20] was followed: ICD B34.2, infections caused by a coronavirus, along with one of the COVID-19 markers (U07.1 — laboratory-confirmed case) or U07.2 (probable or suspected case — clinical, epidemiological history with inconclusive or unavailable tests) on the same line of the DC.

Statistical analysis

Losses due to the non-linkage of the bases were compared with the NDs related to SINASC. The data source to test the homogeneity of the non-linkage losses was the SIM

(maternal education and age, gender, weight, gestational age, and age of death). The NMR (quotient between the number of neonatal deaths by the number of LBs in 2021) per thousand LBs and the confidence interval (95%CI) were calculated. The absolute and percentage distributions of the variables studied were described for neonatal survivors and age at death. As gestational age information didn't compose the prenatal inadequacy variable, this variable was additionally analyzed according to prematurity (<37 s: yes/no). To test the homogeneity of the loss *versus* linked NDs and the survival *versus* the death of the study population, the Pearson's χ^2 and Fisher's exact tests (statistical significance level of 5%) were used.

To investigate the factors associated with ND, simple nominal (significance level <0.2) and multiple (significance level <0.5) logistic regression models were used. The strategy of the theoretical model of hierarchical determination of the ND[21] was applied, adapted according to available data from the information systems. The distal hierarchical level was represented by maternal education and color; intermediate level I, by maternal age group and parity; intermediate II, due to fetal presentation and adequacy of prenatal care; and, at the proximal level, by characteristics of the newborn (weight, gestational age, and Apgar at the 5th minute) except for the gender variable (not belonging to the hierarchical levels), approached independently, and considered without adjustments (Supplementary Figure 1). Covariates from the same and previous hierarchical levels were considered as potential confounders. The computer program Stata SE (version 12) was used.

This study was approved by the Research Ethics Committee of Universidade Federal Fluminense (No. 29721320.0.0000.5243, opinion 4.091.556, of June 16th, 2020).

RESULTS

SIM records not linked to SINASC corresponded to 12% of deaths (194 losses out of 1,618 ND). When applying the eligibility criteria, this percentage reduced to 9.9% (109 losses out of 1,099 ND). The losses were not selective regarding age at death and maternal and neonatal characteristics. In the cohort of 179,837 LB, 274 ND occurred within 24 hours, 447 from one to six days and 324 from seven to 27 days (Supplementary Figure 2). Neonatal mortality rate was 5.8‰ LB (95%CI 5.5–6.2).

Survivals and deaths in the neonatal period were heterogeneous, except for reproductive history (Table 1). The proportions of teenage mothers (<20 years) and those aged ≥35 years were more frequent among deaths than survivors. Among the survivors, mothers with high education, white, with prenatal care, and a fetus in the cephalic presentation were more prevalent. The neonates who died were predominantly male, with a higher frequency of low birth weight, prematurity, and asphyxia in the 5th minute (Table 1).

In the analysis of deaths by age (Table 1), those that occurred within 24 hours had the highest proportion of inadequate prenatal care and non-cephalic presentation and the lowest proportion of vaginal deliveries. The inadequacy of prenatal care was highlighted for deaths within 24 hours in premature neonates (35.4%), 40% higher than in non-premature neonates (25.3%). Regarding weight, gestational age, and Apgar at the 5th minute, a more disadvantageous situation was observed than in the other deaths (Table 1). Deaths from one to six days, the most numerous, showed a high proportion of cesarean sections and a higher frequency of males. Late ND showed a higher frequency of mothers in the extremes of age, with low education and black. A decreasing gradient in the proportion of mothers with 12 years and more of education and an increasing gradient in the proportion of maternal black color were observed between survivors and deaths and, among deaths, with increasing age.

Of the deaths, 70.4% were investigated (66% of ND<24 hours and 72% of the others ND), and 74% were classified as avoidable. The causes reducible by adequate care for the pregnant woman (first position) and adequate care for the newborn (second position) were highlighted (Table 2). Some differences were observed in the analysis of avoidability by age: among the ND<24 hours, the group of other causes (not clearly avoidable, which include most congenital malformations) occupies the second position, followed by causes reducible by adequate attention to the childbirth. The 1-6 days ND follow the pattern of the total: higher percentage for causes reducible by adequate care for pregnant women. There is an inversion of this pattern to the late deaths: the first cause is adequate attention to the newborn. Deaths classified in the groups of causes reducible by adequate diagnostic and treatment and health promotion actions are much less frequent and restricted to ages 1–6 and 7–27 days. Ill-defined causes are rare at all ages, and there were no deaths from vaccine-avoidable causes (Table 2).

The most frequent grouping of cause of death was specific infections in the perinatal period (ICD P35 to P39.9), more pronounced for the 1–6 and 7–27 days groups (Table 2). In this group, the specific cause of unspecified bacterial septicemia of the newborn (ICD P36.9) stood out with 121 cases, first among the specific causes, except for ND<24 hours, among which other congenital malformations prevailed (ICD Q89) (Supplementary Table 1). In second place came maternal conditions (CID P00) (Table 2). For ND<24 hours, the first cause was intrauterine hypoxia and birth asphyxia (ICD P20 and P21). Three late neonatal deaths had a mention of COVID-19 (CID B34.2 and U07.1 or U07.2 in the same line of the DC), with the underlying causes being coronavirus infection of unspecified location (CID B34.2) and asphyxia at birth, unspecified (ICD P21.9).

In the crude analysis, all variables were associated with ND (p<0.20) (Supplementary Table 2), with greater magni-

Table 1. Absolute and percentage distribution of maternal, reproductive, pregnancy, childbirth and newborn characteristics of the live birth cohort, state of Rio de Janeiro, 2021.

Characteristics	Neonatal survivors		Neonatal deaths						p
			<24 hours		1–6 days		7–27 days		
	n	%	n	%	n	%	n	%	
Age range (years)									
<20	22,181	12.4	42	15.3	67	15.0	56	17.3	0.002
20–34	125,283	70.1	178	65.0	293	65.6	198	61.1	
≥35	31,328	17.5	54	19.7	87	19.5	70	21.6	
Education (years)									
0–3	1,919	1.1	3	1.2	4	0.9	6	1.9	0.035
4–11	133,881	76.6	215	82.1	366	83.2	261	83.1	
≥12	38,908	22.3	44	16.8	70	15.9	47	15.0	
Race/color									
White	56,777	32.7	73	28.6	115	26.4	82	26.1	<0.001
Black	25,371	14.6	42	16.5	77	17.7	67	21.3	
Brown	91,362	52.7	140	54.9	244	56.0	165	52.6	
Deceased children/miscarriages									
None	139,222	99.6	201	100.0	337	98.8	229	100	0.163
≥1	538	0.4	0	0.0	4	1.2	0	0.0	
Alive children									
None	75,866	43.2	120	44.4	197	44.2	155	48.3	0.103
1–3	92,968	52.9	136	50.4	228	51.1	147	45.8	
≥4	6,949	4.0	14	5.2	21	4.7	19	5.9	
Previous births									
0	74,765	42.5	115	42.6	192	43.1	148	46.3	0.591
≥1	101,214	57.5	155	57.4	254	57.0	172	53.8	
Inadequate prenatal care									
Yes	38,427	21.8	88	33.1	127	28.7	97	30.5	<0.001
No	137,502	78.2	178	66.9	316	71.3	221	69.5	
Cephalic presentation									
Yes	170,983	97.2	207	79.3	376	85.1	281	88.4	<0.001
No	4,980	2.8	54	20.7	66	14.9	37	11.6	
Type of delivery									
Vaginal	75,940	42.5	143	52.6	184	41.2	165	50.9	<0.001
Caesarean	102,738	57.5	129	47.4	263	58.8	159	49.1	
Gender									
Female	87,532	49.0	124	45.6	176	39.4	145	44.9	<0.001
Male	91,244	51.0	148	54.4	271	60.6	178	55.1	
Weight (grams)									
500 to 1,499	1,400	0.8	152	55.5	249	55.7	148	45.7	<0.001
1,500 to 2,499	10,317	5.8	60	21.9	67	15.0	66	20.4	
2,500 to 3,999	158,733	88.8	60	21.9	121	27.1	108	33.3	
≥4,000	8,342	4.7	2	0.7	10	2.2	2	0.6	
Gestational age (weeks)									
23–31	1,456	0.8	145	55.8	241	54.9	141	44.8	<0.001
32–36	14,667	8.4	67	25.8	86	19.6	77	24.4	
≥37	159,403	90.8	48	18.5	112	25.5	97	30.8	
Apgar 5th minute									
<7	1,259	0.7	208	80.0	144	33.4	1.689	1.0	<0.001
≥7	175,875	99.3	52	20.0	287	66.6	176.448	99.1	

Source: State Health Department of the state of Rio de Janeiro. Information Systems on Mortality and Live Births.

tude at proximal and intermediate levels II. In the multiple model, the male gender was exclusively associated with deaths from one to six days (p<0.05) (Table 3). Distal level variables were not significant for ND<24 hours. Low education was significant (p=0.048) only for ND of 7–27 days and brown color for ND of 1–6 days. The maternal black color was associated with ND at 1–6 and 7–27 days. At the intermediate level I, primiparity was not selected, and adolescent and ≥35-year-old mothers were associated only with late ND. The other variables at the intermediate and proximal levels remained strongly associated with ND, regardless of age (Table 3).

DISCUSSION

In the 2021 birth cohort in Rio de Janeiro, for every thousand LB, about six died in the neonatal period, or a little more than ¼ of deaths in less than one day. Causes of death, associated factors, and strength of association differed according to age of death, confirming the importance

Table 2. Neonatal deaths by age, according to avoidability* and main causes†, state of Rio de Janeiro, 2021 live birth cohort.

Avoidability group (LBE)* and main cause (ICD)†	<24 hours (n=274)		1–6 days (n=447)		7–27 days (n=324)		Total (n=1,045)	
	n	%	n	%	n	%	n	%
1) Avoidable	185	67.5	359	80.3	229	70.7	773	74.0
Reducible by adequate care during pregnancy	90	32.9	168	37.6	65	20.1	323	30.9
• Maternal disorders (P00)	26		63		26		115	
Reducible by adequate delivery care	56	20.4	78	17.5	34	10.5	168	16.1
• Intrauterine Hypoxia and Asphyxia (P20, P21)	30		37		19		86	
Reducible by adequate newborn care	39	14.2	111	24.8	122	37.7	272	26.0
• Specific perinatal infections (P35 to P39.9)	17		71		65		153	
Reducible by proper diagnosis and treatment	-	-	1	0.2	5	1.5	6	0.6
Reducible by adequate health promotion	-	-	1	0.2	3	0.9	4	0.4
2) Poorly defined	2	0.7	5	1.1	3	0.9	10	1.0
3) Other causes	87	31.8	83	18.6	92	28.4	262	25.1

Source: State Health Department of the state of Rio de Janeiro. Information Systems on Mortality and Live Births.
*LBE: Brazilian List of Avoidable Causes of Death (*Lista Brasileira de causas de mortes evitáveis por intervenções do Sistema Único de Saúde do Brasil*);
†ICD: International Classification of Diseases

Table 3. Multiple hierarchical model of age-specific neonatal mortality, state of Rio de Janeiro, 2021 live birth cohort.

Hierarchical level and Variables	<4 hours				1–6 days				7–27 days			
	p-value	OR*	95%CI†		p-value	OR*	95%CI†		p-value	OR*	95%CI†	
Male	0.266	1.1	0.9	1.5	**<0.001**	1.5	1.2	1.8	0.144	1.2	0.9	1.5
Distal												
<8 years of study	0.239	1.2	0.9	1.7	0.134	0.9	1.0	1.6	**0.048**	1.3	1.0	1.8
Brown color	0.224	1.2	0.9	1.6	**0.026**	1.3	1.0	1.6	0.263	1.2	0.9	1.5
Black color	0.217	1.3	0.9	1.9	**0.009**	1.5	1.1	2.0	**0.001**	1.8	1.3	2.5
Intermediate I												
<20 years	0.178	1.3	0.9	1.8	0.175	1.2	0.9	1.6	**0.013**	1.5	1.1	2.0
≥35 years	0.137	1.3	0.9	1.8	0.093	1.2	1.0	1.6	**0.008**	1.5	1.1	2.0
Intermediate II												
Inadequate prenatal care	**<0.001**	6.3	4.7	8.5	**<0.001**	4.5	3.7	5.6	**<0.001**	4.0	3.1	5.2
Non-cephalic fetal presentation	**<0.001**	9.0	6.4	12.7	**<0.001**	6.4	4.9	8.5	**<0.001**	4.6	3.2	6.8
Proximal												
<1,500g	**<0.001**	6.1	2.5	14.6	**<0.001**	13.1	7.2	23.8	**<0.001**	13.8	6.9	27.2
1,500–2,499g	**0.003**	2.8	1.4	5.4	**<0.001**	2.5	1.6	4.0	**<0.001**	3.4	2.1	5.6
≥4,000g	0.947	1.0	0.2	4.0	0.054	1.9	1.0	3.7	0.309	0.5	0.1	2.0
23–32 weeks	**<0.001**	7.6	3.1	18.7	**<0.001**	10.6	5.7	19.7	**<0.001**	7.9	3.9	15.8
32–36 weeks	**0.002**	2.8	1.5	5.5	**<0.001**	3.6	2.4	5.6	**<0.001**	3.1	1.9	5.0
Apgar 5'<7	**<0.001**	151.4	101.8	225.2	**<0.001**	13.7	10.4	18.2	**<0.001**	8.9	6.3	12.7

*OR: odds ratio; †95%CI: 95% confidence interval; numbers in bold highlight the categories of variables that are factors associated with each specific age of death, considering the level of statistical significance (p-value). Note: OR values were adjusted for gender and covariates belonging to the same and higher hierarchical level(s).

of age-specific analysis. Avoidable causes of death prevail in the neonatal period: those related to adequate care during pregnancy, more frequently in deaths <24 hours, and to the newborn, in deaths from 1 to 27 days. Particularly for late NDs, there was mention of COVID-19 in the DC. Maternal vulnerabilities, such as low education and black and mixed race, were relevant risk factors for deaths from the first day of life. Care variables, such as inadequate prenatal care and non-cephalic presentation, as well as newborn characteristics, such as weight, gestational age, and Apgar at the 5th minute, were strongly associated with ND, regardless of age.

Neonatal mortality rates in cohort studies with longitudinal data, are close to the values obtained with cross-sectional data (deaths and LB in the same year) due to the short follow-up period (up to 27 days). The NMR of the present study and that calculated with the cross-sectional data available on the website of the State Health Department of RJ were very close. NMR estimates were not found in national cohort studies for the current decade. In the previous decade, lower NMR values were estimated in cohorts of LB from Florianópolis city, state of Santa Catarina, from 2012 to 2014 (5.4‰ LB)[10] and from the Rio de Janeiro city, state of Rio de Janeiro, in 2015 (5.9‰ LB)[12]. On the other hand, in Goiânia city, state of Goiás, in 2012 (9.4‰ LB)[13], in the state of São Paulo, from 2004 to 2013 (from 9.1 to 7.4‰ LB)[14], and in Pelotas city, state of Rio Grande do Sul, in 2015 (8.7 ‰ LB)[11], the values were higher than those of the present study (5.8 ‰ LB), even considering the deaths not related in the present study (n=1,090), which would increase NMR to 6.4 per thousand LB. It should be highlighted that there has been a decline in neonatal mortality in the country, and probably the values of the current decade for the mentioned places have reduced, mainly in the southern region of the country, whose NMR in 2018 was estimated at 7.2‰ LB[2].

The group of causes reducible by adequate pregnancy care was the most frequent, corroborating the national study by Prezotto et al.[22]. The order of magnitude of reducible causes of death in Brazil was the same as the one found in the current investigation for the state of RJ. The observed lower adequacy of prenatal care among pregnant women whose newborns died supported this finding. It is noteworthy that, in the mentioned research, the avoidable NMR of the state of Rio de Janeiro was 6.5 per thousand LB, the highest in the Southeast[22].

There was a difference in the pattern of causes and avoidability according to the neonatal age range. The closer to birth, in addition to maternal causes, the more lethal congenital malformations and asphyxia had an impact. The later the death, causes reducible by attention to the newborn, especially the specific perinatal infection, had considerable importance. However, the high frequency of diagnosis of unspecified bacterial septicemia in the newborn deserves reflection (ICD P36.9), which does not contribute to the knowledge of the causes of death. This condition was responsible for about 80% of infant deaths from sepsis in Brazil[23], of which 80% were preterm and/or had low birth weight. Therefore, unspecified sepsis is hardly the underlying cause and can be considered a garbage code[24]. Other debatable diagnoses as the underlying cause are those related to intrauterine hypoxia (ICD P20) and birth asphyxia (ICD P21), attributed in the LBE classification to childbirth care but which may result from maternal causes not detected during prenatal care[25].

Despite not being among the most frequent causes of neonatal deaths in the studied cohort, two infectious diseases deserve to be highlighted as a public health problem: congenital syphilis (ICD A50), neglected and endemic disease (0.7; 2.9 and 1.9%, respectively, of deaths <24 hours, 1–6 days, and 7–27 days) (Supplementary Table 1), and the before mentioned cause COVID-19, emerging and pandemic disease (data not shown in table). An increasing trend of congenital syphilis from 2001 to 2017 in the state of Rio de Janeiro, the highest in the Southeast Region in 2017, was observed even considering prenatal care, which therefore reflects failures in maternal and child care[26].

In a meta-analysis on the impact of COVID-19 on maternal and fetus health, an increase in prematurity and low birth weight was observed, but the risk of neonatal death was considered low[27]. In the 2021 state of RJ birth cohort of 324 late NDs, two cases of COVID-19 were considered suspect and one, confirmed.

As for the associated factors, the differences according to the specific age of death occurred only in the distal and intermediate I hierarchical levels and with the gender variable. None of these factors was associated with death <24 hours, and maternal education and age were associated only with the late component of ND. Even using the hierarchical modelling analysis, which favors the maintenance of distal determinants along the causal chain, the distal factors associated with neonatal death in other studies are not consensual. In national LB cohorts, factors such as schooling, color, and marital status in Goiânia (GO)[13], color and schooling in Pelotas (RS)[11], and schooling and marital status in Florianópolis (SC)[10] were not associated with neonatal mortality due to early and late[13] and total[10,11] components. In the LB cohort from the city of Rio de Janeiro (RJ), education and color (distal level) were associated with total neonatal death[12]. In a recent meta-analysis, the authors concluded that for each additional year of maternal education, there is a 1.5% reduction in total neonatal mortality[28]. Care and newborn factors, closer to the outcome, regardless of age at death, were strongly associated. Four or more prenatal visits reduce the chance of dying on the first day of life by 30% in countries in Latin America, the Caribbean, Africa, and Asia[29]. In 2015, the state of Rio de Janeiro had the highest proportion of inadequate prenatal care (29.5%) when compared to other states in the

Southeast[2]. In the present study, using the same indicator of adequacy of access to prenatal care, the proportion of inadequacy was high but lower, around 25%; however, when comparing deaths with survivors, the adjusted odds ratios (OR) showed a decreasing gradient with increasing age (6.3, 4.5, and 4.0, respectively, for ND<24 hours, 1–6 and 7–27 days). The same gradient of the strength of association with age occurred with the non-cephalic presentation, which makes up the same intermediate level of prenatal care, in agreement with the results of two national studies[12,30]. The type of delivery variable was not incorporated in our model because of the ambiguity of the risk of death or iatrogenic cesarean sections[14]. Strong associations of proximal factors determining neonatal death, weight, gestational age, and Apgar at the 5th min are results widely documented[10-13,15,31,32]. Some of these studies incorporated the gender of the LB at the proximal level of the model[11]. We found it inappropriate because the variables of the previous hierarchical levels don't determine the gender of the newborn.

As positive points of the study, we highlight some methodological aspects. The quality of the SINASC and SIM, as a function of the completeness of the SLB number field in the DC, the linkage key (loss of 9.9%), allowed to reconstitute the 2021 state of RJ birth cohort and as well as the completeness of most of the other variables analyzed, to investigate neonatal mortality and associated factors. We found appropriate the use of the number of vaginal deliveries and the number of previous cesarean deliveries variables to represent parity. Despite the alternative to the definition of parity, based on the information in the database, which would consider both the variable alive children and deceased children/miscarriages, this second variable had a high incompleteness (22%) and included miscarriage in its measurement. Although the reliability of the information was not evaluated in the study, there are publications on the improvement of national[33] and state[34] information contained in the SLB and DC. As for the underlying cause of death, according to the LBE, the frequency of ill-defined causes was low, probably due to the investigation of infant death. In the analyzed cohort, about 70% of the ND were investigated, with the lowest percentage of death investigation for the ND<24 hours (66.1%), which concentrates newborns below 2,500 g, not a priority in the epidemiological surveillance of infant death. However, we questioned some causes of garbage codes. Thus, efforts are imperative to improve the filling out of the SLB and DC.

Another positive aspect of the study was the methods used. The strategy of hierarchical analysis of the determination of the ND allows for preserving the strength of the associations of social determinants (distal level), even after incorporating variables at the more proximal levels of the model[35]. In the multinomial regression model, the effects of the regressors (OR) are adjusted by the same covariates for each specific age of neonatal death (outcome) analyzed, allowing a direct comparison of the results[11,31].

Neonatal mortality in the state of RJ in 2021 was 5.8‰ LB, concentrated in the first 24 hours and 1–6 days. NMR was lower than in previous years, but mostly from avoidable causes, resulting mainly from adequate care for pregnant women. The analysis of associated factors showed inequalities regarding maternal age, schooling, and color, in addition to reinforcing the biological determinants of the newborn. Investments in attention to the mother-child binomial are necessary, especially in prenatal care and in the most vulnerable women.

REFERENCES

1. World Health Organization. United Nations Inter-Agency Group for Child Mortality Estimation. Levels and trends in child mortality: report 2021 [Internet]. 2021 [cited on Sep. 30, 2022]. Available at: https://www.who.int/publications/m/item/levels-and-trends-in-child-mortality-report-2021
2. Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Análise em Saúde e Vigilância de Doenças não Transmissíveis. Saúde Brasil 2020/2021: uma análise da situação de saúde e da qualidade da informação. Brasília: Ministério da Saúde; 2021.
3. Bernardino FBS, Gonçalves TM, Pereira TID, Xavier JS, Freitas BHBM, Gaíva MAM. Trends in neonatal mortality in Brazil from 2007 to 2017. Cien Saude Colet 2022; 27(2): 567-78. https://doi.org/10.1590/1413-81232022272.41192020
4. Teixeira JAM, Araujo WRM, Maranhão AGK, Cortez-Escalante JJ, Rezende LFM, Matijasevich A. Mortalidade no primeiro dia de vida: tendências, causas de óbito e evitabilidade em oito Unidades da Federação brasileira, entre 2010 e 2015. Epidemiol Serv Saude 2019; 28(1): e2018132. https://doi.org/10.5123/s1679-49742019000100006
5. Sankar MJ, Natarajan CK, Das RR, Agarwal R, Chandrasekaran A, Paul VK. When do newborns die? A systematic review of timing of overall and cause-specific neonatal deaths in developing countries. J Perinatol 2016; 36(Suppl 1): S1-S11. https://doi.org/10.1038/jp.2016.27
6. Kale PL, Fonseca SC, Oliveira PWM, Brito AS. Tendência da mortalidade fetal e infantil segundo evitabilidade das causas de morte e escolaridade materna. Rev Bras Epidemiol 2021; 24(suppl 1): E210008. https://doi.org/10.1590/1980-549720210008.supl.1
7. Cadeira ACT, Siqueira AEOB, Leite LRB, Araújo APM, Nascimento CM, Santana DS, et al. Mortalidade neonatal precoce por causas evitáveis na região do Cariri. Brazilian Journal of Development 2021; 7(8): 80062-74. https://doi.org/10.34117/bjdv7n8-291
8. Veloso FCS, Kassar LML, Oliveira MJC, Lima THB, Bueno NB, Gurgel RQ, et al. Analysis of neonatal mortality risk factors in Brazil: a systematic review and meta-analysis of observational studies. J Pediatr (Rio J) 2019; 95(5): 519-30. https://doi.org/10.1016/j.jped.2018.12.014

9. Fonseca SC, Flores PVG, Camargo Jr KR, Pinheiro RS, Coeli CM. Maternal education and age: inequalities in neonatal death. Rev Saúde Pública 2017; 51: 94. https://doi.org/10.11606/S1518-8787.2017051007013

10. Garcia LP, Fernandes CM, Traebert J. Risk factors for neonatal death in the capital city with the lowest infant mortality rate in Brazil. J Pediatr (Rio J). 2019; 95(2): 194-200. https://doi.org/10.1016/j.jped.2017.12.007

11. Varela AR, Schneider BC, Bubach S, Silveira MF, Bertoldi AD, Duarte LSM, et.al. Mortalidade fetal, neonatal e pós-neonatal e fatores associados na coorte de nascimentos de 2015 de Pelotas, Rio Grande do Sul, Brasil. Cad Saúde Pública 2019; 35(7): e00072918. https://doi.org/10.1590/0102-311X00072918

12. Rocha NM, Kale PL, Fonseca SC, Brito AS. ***Near miss*** e mortalidade neonatal e fatores associados: estudo de coorte de nascimentos do município do Rio de Janeiro, RJ. 2021. Rev Paul Pediatr 2023; 41. https://doi.org/10.1590/1984-0462/2023/41/2021302

13. Saloio CA, Morais Neto OL, Gonçalves DA, Bessa HEM, Coelho Junior JP, Afonso MSM, et al. Magnitude e determinantes da mortalidade neonatal e pós-neonatal em Goiânia, Goiás: um estudo de coorte retrospectivo, 2012. Epidemiol Serv Saude 2020; 29(5): e2020132. https://doi.org/10.1590/S1679-49742020000500008

14. Guinsburg R, Sanudo A, Kiffer CRV, Marinonio ASS, Costa-Nobre DT, Areco KN, et al. Annual trend of neonatal mortality and its underlying causes: population-based study – São Paulo State, Brazil, 2004-2013. BMC Pediatr 2021; 21(1): 54. https://doi.org/10.1186/s12887-021-02511-8

15. Castro ECM, Leite AJM, Guinsburg R. Mortalidade com 24 horas de vida de recém-nascidos pré-termo de muito baixo peso da Região Nordeste do Brasil. Rev Paul Pediatr 2016; 34(1): 106-13. http://dx.doi.org/10.1016/j.rppede.2015.12.008

16. Deng Y, Wang R, Zhou X, Ren L, Liu L. Fetal, neonatal, and infant death in central China (Hubei): a 16-year retrospective study of forensic autopsy cases. Medicine (Baltimore) 2019; 98(23): e15788. https://doi.org/10.1097/MD.0000000000015788

17. Brasil. Ministério da Saúde. Como nascem os brasileiros: uma análise da adequação da assistência pré-natal e das indicações de cesárea por critérios de risco epidemiológico a partir do Sinasc. In: Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Vigilância de Doenças e Agravos não Transmissíveis e Promoção da Saúde. Saúde Brasil 2017: uma análise da situação de saúde e os desafios para o alcance dos objetivos de desenvolvimento sustentável. Brasília: Ministério da Saúde; 2018. p. 19-38.

18. Organização Mundial de Saúde. Classificação Estatística Internacional de Doenças e Problemas Relacionados à Saúde. 10ª revisão. São Paulo: Organização Mundial de Saúde; 2000.

19. Malta DC, Sardinha LMV, Moura L, Lansky S, Leal MC, Szwarcwald CL, et al. Atualização da lista de causas de mortes evitáveis por intervenções do Sistema Único de Saúde do Brasil. Epidemiol Serv Saúde 2010; 19(2): 173-6. http://dx.doi.org/10.5123/S1679-49742010000200010

20. Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Análise de Situação de Saúde e Vigilância de Doenças não Transmissíveis. Orientações sobre novos códigos de emergência para as causas de morte relacionadas a condições que ocorrem no contexto da covid-19. Brasília: Ministério da Saúde; 2022.

21. Lima S, Carvalho ML, Vasconcelos AGG. Proposta de modelo hierarquizado aplicado à investigação de fatores de risco de óbito infantil neonatal. Cad Saúde Pública 2008; 24(8): 1910-6. https://doi.org/10.1590/S0102-311X2008000800019

22. Prezotto KH, Oliveira RR, Pelloso SM, Fernandes CAM. Tendência da mortalidade neonatal evitável nos Estados do Brasil. Rev Bras Saude Mater Infant 2021; 21(1): 301-9. https://doi.org/10.1590/1806-93042021000100015

23. Rodrigues LS, Rodrigues LS, Costa LC, Fontoura GMG, Maciel MCG. Trend in infant mortality rate caused by sepsis in Brazil from 2009 to 2018. Rev Invet Med Trop Sao Paulo 2021; 63: e26. https://doi.org/10.1590/S1678-9946202163026

24. Santos MR, Cunha CC, Ishitani LH, França EB. Deaths from sepsis: underlying causes of death after investigation in 60 Brazilian municipalveres in 2017. Rev Bras Epidemiol 2019; 22Suppl 3(Suppl 3): e190012.supl.3. https://doi.org/10.1590/1980-549720190012.supl.3

25. Daripa M, Caldas HMG, Flores LPO, Waldvogel BC, Guinsburg R, Almeida MF. Asfixia perinatal associada à mortalidade neonatal precoce: estudo populacional dos óbitos evitáveis. Rev Paul Pediatr 2013; 31(1): 37-45. https://doi:10.1590/S0103-05822013000100007

26. Oliveira VS, Rodrigues RL, Chaves VB, Santos TS, Assis FM, Ternes YMF, et al. Aglomerados de alto risco e tendência temporal da sífilis congênita no Brasil. Rev Panam Salud Publica 2020; 44: e75. https://doi.org/10.26633/RPSP.2020.75

27. Di Toro F, Gjoka M, Di Lorenzo G, De Santo D, De Seta F, Maso G, et al. Impact of COVID-19 on maternal and neonatal outcomes: a systematic review and meta-analysis. Clin Microbiol Infect 2021; 27(1): 36-46. https://doi.org/10.1016/j.cmi.2020.10.007

28. Balaj M, York HW, Sripada K, Besnier E, Vonen HD, Aravkin A, et al. Parental education and inequalities in child mortality: a global systematic review and meta-analysis. Lancet 2021; 398(10300): 608-20. https://doi.org//10.1016/S0140-6736(21)00534-1

29. Singh K, Brodish P, Suchindran C. A regional multilevel analysis: can skilled birth attendants uniformly decrease neonatal mortality? Matern Child Health J 2014; 18(1): 242-9. https://doi.org/10.1007/s10995-013-1260-7

30. Lansky S, Friche AAL, Silva AAM, Campos D, Bittencourt SDA, Carvalho ML, et al. Birth in Brazil survey: neonatal mortality, pregnancy and childbirth quality of care. Cad Saude Publica 2014; 30 Suppl 1: S1-15. https://doi.org/10.1590/0102-311x00133213

31. Maia LTS, Souza WV, Mendes ACV. Determinantes individuais e contextuais associados à mortalidade infantil nas capitais brasileiras: uma abordagem multinível. Cad Saúde Pública 2020; 36(2): e00057519 https://doi.org/10.1590/0102-311X00057519

32. Kale PL, Mello-Jorge MHP, Silva KS, Fonseca SC. Neonatal near miss and mortality: factors associated with life-threatening conditions in newborns at six public maternity hospitals in Southeast Brazil. Cad Saúde Pública 2017; 33(4): e00179115. https://doi.org/10.1590/0102-311X00179115

33. Szwarcwald CL, Leal MC, Esteves-Pereira AP, Almeida WS, Frias PG, Damacena GM, et al. Avaliação das informações do Sistema de Informações sobre Nascidos Vivos (SINASC), Brasil. Cad Saúde Pública 2019; 35(10): e00214918. https://doi.org/10.1590/0102-311X00214918

34. Lino RRG, Fonseca SC, Kale PL, Flores PVG, Pinheiro RS, Coeli CM. Trend of incompleteness of vital statistics in the neonatal period, State of Rio de Janeiro, Brazil, 1999-2014. Epidemiol Serv Saude 2019; 28(2): e2018131. https://doi.org/10.5123/S1679-49742019000200014

35. Victora CG, Huttly SR, Fuchs SC, Olinto MT. The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. Int J Epidemiol 1997; 26(1): 224-7. https://doi.org/10.1093/ije/26.1.224

RESUMO

Objetivo: Analisar a magnitude dos óbitos neonatais (ON), as causas de morte e os fatores associados por idade específica na coorte de nascidos vivos em 2021, no estado do Rio de Janeiro. **Métodos:** Coorte retrospectiva de nascidos vivos (NV) seguidos até 27 dias do parto (<24 horas, 1–6 e 7–27 dias). Dados obtidos dos Sistemas de Informações sobre Nascidos Vivos (2021) e Mortalidade (2021/2022). Foram descritas as distribuições das características maternas e do recém-nascido, causas de mortes e evitabilidade. Foram utilizados modelos de regressão multinomial com níveis hierárquicos de determinação do ON. **Resultados:** Dos 179.837 NV, morreram 274 até 24 horas, 447 de 1 a 6 dias e 324 de 7 a 27 dias. A taxa de mortalidade neonatal foi 5,8‰ NV (intervalo de confiança — IC95%: 5,5–6,2). Sobreviventes e ON foram heterogêneos segundo caraterísticas analisadas, exceto história reprodutiva (p<0,05). Das causas de morte, 78% eram evitáveis. Predominaram causas reduzíveis por adequada atenção à gestante (<24 horas e 1–6 dias) e ao recém-nascido (7–27 dias). No nível distal, baixa escolaridade mostrou associação significante para óbitos entre 7 e 27 dias ($OR_{ajustado}$=1,3), cor parda, para óbitos de 1–6 dias ($OR_{ajustado}$=1,3) e cor preta, para ambas as idades (1–6: $OR_{ajustado}$=1,5; 7–27 dias: $OR_{ajustado}$=1,8). Fatores assistenciais e biológicos do NV (níveis intermediário e proximal) mantiveram-se fortemente associadas aos ON, independentemente da idade. **Conclusão:** As causas de morte, os fatores associados ao ON e a força de associação diferiram conforme a idade do óbito. Ações preventivas do ON devem considerar vulnerabilidades sociodemográficas e intensificar uma assistência adequada pré-natal e perinatal.

Palavras-chave: Coorte de nascimento. Mortalidade neonatal. Mortalidade neonatal precoce. Causa de morte. Fatores sociodemográficos. Cuidado pré-natal.

AUTHORS' CONTRIBUTIONS: Kale, P.L.: Project administration, Formal analysis, Conceptualization, Data curation, Writing – original draft, Writing – review & editing, Investigation, Methodology. Fonseca, S.C.: Project administration, Formal analysis, Conceptualization, Data curation, Writing – original draft, Writing – review & editing, Investigation, Methodology.

FUNDING: none.