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Contextual determinants of neonatal mortality using two analysis methods, Rio Grande do Sul, Brazil

ABSTRACT

OBJECTIVE: To analyze neonatal mortality determinants using multilevel logistic regression and classic hierarchical models.

METHODS: Cohort study including 138,407 live births with birth certificates and 1,134 neonatal deaths recorded in 2003, in the state of Rio Grande do Sul, Southern Brazil. The Information System on Live Births and mortality records were linked for gathering information on individual-level exposures. Sociodemographic data and information on the pregnancy, childbirth care and characteristics of the children at birth were collected. The associated factors were estimated and compared by traditional and multilevel logistic regression analysis.

RESULTS: The neonatal mortality rate was 8.19 deaths per 1,000 live births. Low birth weight, 1- and 5-minute Apgar score below eight, congenital malformation, pre-term birth and previous fetal loss were associated with neonatal death in the traditional model. Elective cesarean section had a protective effect. Previous fetal loss did not remain significant in the multilevel model, but the inclusion of a contextual variable (poverty rate) showed that 15% of neonatal mortality variation can be explained by varying poverty rates in the microregions.

CONCLUSIONS: The use of multilevel models showed a small effect of contextual determinants on the neonatal mortality rate. There was found a positive association with the poverty rate in the general model, and the proportion of households with water supply among preterm newborns.

DESCRIPTORS: Neonatal Mortality (Public Health). Mortality Registries. Risk Factors. Socioeconomic Factors. Cohort Studies.

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INTRODUCTION

Of the 130 million children born worldwide every year, about 4 million die during the neonatal period, though this proportion depends on the overall mortality rate.[25] Daily risk of death varies significantly and infants are at greatest risk during the first week of life.[11]

Almost all neonatal deaths (99%) are in low- or middle-income countries.[11] Children born in poor countries have a higher risk of death and neonatal mortality rate is 19% to 44% higher in poor families.[10]

In Brazil infant mortality rate fell by 50% between 1990 and 2008. The southern state of Rio Grande do Sul had a reduction from 26.2 deaths per 1,000 live births in 1990 to 13.1 in 2008. During that same period, neonatal mortality (zero to 27 days of age) and post-neonatal (28–364 days of age) in Rio Grande do Sul decreased from 14.7‰ to 8.3‰ and from 11.5‰ to 4.5‰ respectively, showing a significant death reduction in children 28 days old or more.

Mother and child characteristics are analyzed as determinants of child mortality and its components, socioeconomic characteristics, perinatal procedures, management and maternal diseases, birth weight, prematurity, type of childbirth and birth defects have been extensively investigated.[13,15]

Regional and social differences may influence the composition of population groups[9] and the success of local health promotion programs. Living in poor areas can have negative effects on children's health.[19]

Traditional models of analysis assume independence of observations and homogeneity of variance but they do not take into account a hierarchy of predictors, i.e., observations originated from the same unit may be more similar than those coming from different units. It can lead to overestimation of clustering effects and inaccurate conclusions.[9]

Multilevel regression analysis is an alternative method to more traditional models as it takes into account the outcome measured at the individual level and explanatory variables at any level. These models allow a separate analysis of the effect of different levels and provide information on global variability.[9] The literature has recognized its strengths,[9,15] though there is no consensus on the conceptual and operational aspects of the contextual variables used.

Hence, to broaden the understanding of factors associated with neonatal death, the present study aimed to analyze neonatal mortality determinants using multilevel logistic regression analysis and the traditional hierarchical model.

METHODS

Static historical cohort study including 138,407 live births to women living in the state of Rio Grande do Sul, Southern Brazil, and with birth certificates (BC) recorded between January 1st, 2003 and December 3rd, 2003. Deaths were identified by selecting common variables and linking them to birth and death databases (linkage). Survivors were those live newborns with BC not linked to a related DC, assuming no migration or loss of observations during the study period. Fields used for linkage included: code of the mother's residence city, date of birth, gender, birth weight, mother's age, type of delivery and pregnancy. There were excluded 122 certificates due to missing information in the DC.

The dependent variable was occurrence of death or not in children aged less than 28 days.

Information on exposure at the individual level was obtained from BCs and DCs recorded in the Brazilian National Live Birth Database (Sistema de Informações sobre Nascidos Vivos – SINASC) and Death Database (Sistena de Informações sobre Mortalidade – SIM), respectively, included in the Brazilian National Health System Database (DATASUS).

Intrauterine growth charts of Lubchenco,[4] adapted by Souza (2004),[a] provide an expected distribution of weight per gestational age, and they were used as a parameter to detect errors in data records. The following were considered errors: gestational age <22 weeks; birth weight <500 g; gestational age <27 weeks and birth weight > 1500 g; gestational age <31 weeks and birth weight >2500 g; and gestational age >37 weeks and birth weight <1500 g. According to these criteria, there were excluded 175 (0.13%) records, and 14 (0.01%) children whose mother's age did not match their parity (e.g., mother aged 18 with 16 children).

The proximal determinants were: 1- and 5-minute Apgar scores; birth weight; gestational age; number of prenatal visits; gender; single or multiple pregnancy; previous fetal loss; type of delivery; presence of birth defects; in-hospital birth or other; and small for gestational age (simplified SGA). As information on BCs about pregnancy duration at predetermined intervals does not allow the classification of live births by adequacy of weight for gestational age, we used the simplified definition of SGA:[6] live births weighing <2500 g and gestational age >37 weeks.

Intermediate variables included mother's age and parity, and distal determinants included skin color/ethnicity; maternal education; marital status; and mother's occupation (homemaker; employed).

There were evaluated the characteristics that reflect the socioeconomic and demographic background of 35 microregions in Rio Grande do Sul and that, based on the theoretical reference, are major determinants of child mortality and its components:[13,15] urbanization (proportion of urban residents); life expectancy at birth (average number of years that a newborn is expected to live from birth); fecundity (average number of children a woman would have during their childbearing years); illiteracy (percentage of people aged 15 or more who are unable to read or write a short, simple statement); mean years of schooling; poverty rate (percentage of people with per capita household income less than half

[a] Souza LM. Avaliação do Sistema de Informação sobre Nascidos Vivos – SINASC, Minas Gerais e Mesorregiões [Master's dissertation]. Belo Horizonte: Universidade Federal de Minas Gerais; 2004.

the minimum wage); hospitalization rate due to assault, murder; participation in the labor market (percentage of economically active people at productive age); gross domestic product (per capita GDP); household density (percentage of people living in households with a density greater than two); immunization coverage in the first year of life (tuberculosis [Bacille Calmette-Guerin – BCG], measles); Family Health Strategy (percentage of people enrolled); water supply (proportion of households with water supply system) and sanitation system (percentage of households with sanitation system); proportion of cesarean deliveries; proportion of women attending seven or more prenatal care visits; health insurance (percentage of people with private insurance for consultations, tests or hospitalizations); proportion of physicians (including resident doctors) and hospital beds per 1,000 inhabitants; and per capita spending with primary care.

The variables were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE – Brazilian Institute of Geography and Statistics); DATASUS National Immunization Program, Primary Care Database, and Brazilian National Agency for Supplementary Health Care; Institute of Applied Economic Research; Foundation of Economics and Statistics; National System of Urban Indicators; and Socioeconomic Atlas of Rio Grande do Sul.

The contextual variables were evaluated in a continuous scale (centered on the average), in quintiles or quartiles, or dichotomized.

Univariate and multivariate analyses were performed to test the association of predictors with neonatal mortality and measures of association included crude and adjusted odds ratios (ORs) and their related 95% confidence intervals.

Multiple logistic regression was used to adjust for confounders, and the Wald test and likelihood ratio test were used to examine the significance of the models.

The hierarchical model was adapted as proposed by Mosley & Chen (1984)[17] to identify determinants of child mortality in developing countries. Biological and social variables were divided into proximal (child health status), intermediate (maternal factors) and distal (socioeconomic and health service in the microregions). The variables were included in the model step by step and those with p<0.25 in the univariate analysis were included in the model.

Live births were included, even those with missing information for some variables.

For the selection of contextual variables, in addition to the theory reference, a correlation analysis was conducted to assess multicollinearity.

The analysis included all live births divided by preterm and full-term gestational age.

The multilevel logistic regression analysis took into account inherent data hierarchy: microregions (cluster of neighboring municipalities intended to integrate the organization, planning and implementation of shared public functions) as level 2 and live births as level 1. A random intercept model was adjusted assuming that all coefficients of the multilevel regression model are the same for all the regions, but their intercepts may vary.

At the end of each stage, statistical significance of the estimates and the variation at each level were assessed, and then estimated the Bayesian deviance information criterion (DIC) for model comparison and selection.[9]

Traditional and multilevel analyses were performed using SPSS 13.0 (SPSS Inc., Chicago, USA) and MLwiN 2.02 (Center for Multilevel Modeling, Bristol, UK), respectively.

The study was approved by the Research Committee at Universidade Federal do Rio Grande do Sul (UFRGS) School of Medicine, and approval by a research ethics committee was not required as secondary data of public domain were used.

RESULTS

The proportion of newborns classified as SGA was 4.1%. The percentage of cesarean sections was 44.7% for the total population of newborns, and was higher (57.5%) among children born with very low birth weight (<1500 g) and premature infants (52.4%).

The neonatal mortality rate was 8.19 ‰, 5.55 ‰ in the early neonatal and 2.64 ‰ in the late neonatal period.

A total of 769 (67.8%) of deaths occurred in the early neonatal period (zero to six days of age), of which 587 (76.3%) had birth weight <2500 g and 173 (22.5%) very low birth weight. Of the 365 (32.2%) late neonatal deaths (seven to 27 days of age), 269 (73.7%) were children born with low birth weight and 173 (47.4%) with very low birth weight.

Among deaths, the mean weight was 1,700.26 g (standard deviation [SD] = 968.57), the average 1- and 5-minute Apgar scores were 4.68 (SD = 2.93) and 6.33 (SD = 2.87) and cesarean rate was 41.4%.

Newborns characteristics, the mortality rate and the results of the univariate analysis and traditional logistic regression are presented in Table 1. Table 2 shows the results for preterm and full-term newborns.

The results of the multilevel logistic regression are presented in Table 3. The model for full-term newborns showed no significant residual variance at microregion level (p = 0.266).

A model without covariates was initially designed with a hierarchical structure and variability of microregions.

The extra-binomial variation at level 1 (over-dispersion = 0.993) showed no significant evidence that the data did not follow a binomial distribution.

The estimate of the residual variance at the microregion level was significant (p = 0.011) for the entire cohort of newborns. The estimated within microregion correlation[9] indicated that most of the outcome variance (97.7%) occurred among individuals, and that 2.3% are due to variation between microregions.

Poverty rate, hospitalization rate due to assault and life expectancy at birth remained significant in the combined analysis of individual-level and contextual variables. However, when they were included in the model at the same time, only poverty rate, dichotomized at the 66th percentile (28.5%), remained significant.

The reduction in the model variance indicates that about 15% of the variation in neonatal mortality can be explained by poverty rate in each area.

The residual variance of the model without covariates at the microregion level was significant (p = 0.004) for preterm newborns, which suggests that 5.4% of the outcome variance was due to variability between microregions.

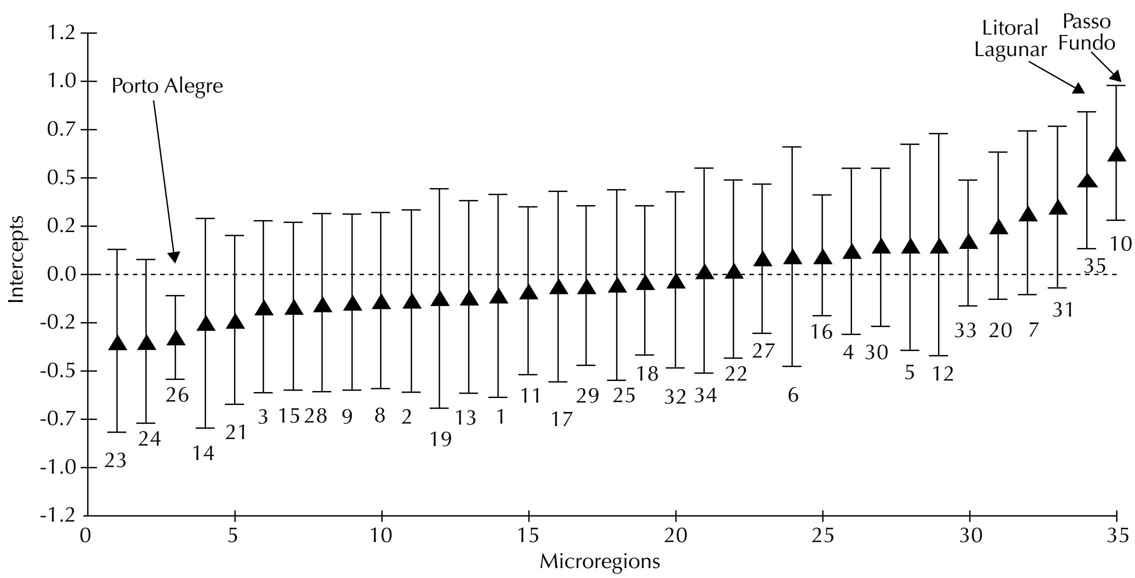
In this model, only the proportion of households with water supply system, dichotomized at the median (71.7%), was statistically significant. The inclusion of the contextual variable after the inclusion of individual variables reduced the variance, which suggests that about 21% of the variability in neonatal mortality can be explained by the coverage of water supply in each area.

For the analysis of residues of the model for preterm newborns, the lowest estimated risk of neonatal death compared to the overall mean was seen in the microregion of Porto Alegre (state capital), while the estimates were not significantly different from the mean for all other microregions.

The Figure illustrates the residual variance between microregions in the general model, in order of magnitude, in which two subpopulations are associated with a particular low or high risk of death. The lowest predicted risk of neonatal death is seen in the microregion of Porto Alegre and the highest risks are seen in the microregions of Passo Fundo and Litoral Lagunar. The risks were not significant in the remaining microregions.

DISCUSSION

Rio Grande do Sul has one of the best SINASC and SIM coverages, allowing record linkage in cohort studies. There were inconsistencies and missing information, as reported in other studies,[1,24] but their relative weight was small in this study. A study conducted in all Brazilian states in 2002 pointed to SINASC as a potential source



Note: (1) Santa Rosa, (2) Três Passos, (3) Frederico Westphalen, (4) Erechim, (5) Sananduva, (6) Cerro Largo, (7) Santo Ângelo, (8) Ijuí, (9) Carazinho, (10) Passo Fundo, (11) Cruz Alta, (12) Não-me-Toque, (13) Soledade, (14) Guaporé, (15) Vacaria, (16) Caxias do Sul, (17) Santiago, (18) Santa Maria, (19) Restinga Seca, (20) Santa Cruz, (21) Lajeado-Estrela, (22) Cachoeira do Sul, (23) Montenegro, (24) Gramado-Canela, (25) São Jerônimo, (26) Porto Alegre, (27) Osório, (28) Camaquã, (29) Campanha Ocidental, (30) Campanha Central, (31) Campanha Meridional, (32) Serras de Sudeste, (33) Pelotas, (34) Jaguarão and (35) Litoral Lagunar

Figure. Ordered reduced residuals of the general model at the microregion level and related 95% confidence intervals. Rio Grande do Sul, Southern Brazil, 2003..

Table 1. Risk factors for neonatal mortality. Rio Grande do Sul, Southern Brazil, 2003.

Variables	Live births (%)	Survival (%)	Death (%)	Neonatal mortality rate (1000)	Crude OR (95% CI)	Adjusted OR[a] (95% CI)
Gender						
Female	67,117 (48.49)	66,604 (48.52)	513 (45.40)	7.64	1	1
Male	71,284 (51.51)	70,667 (51.48)	617 (54.60)	8.66	1.13 (1.00;1.27)	-
Skin color/ethnicity						
White	123,254 (89.22)	122,296 (89.25)	958 (85.00)	7.77	1	1
Other	14,897 (10.78)	14,728 (10.75)	169 (15.00)	11.34	1.46 (1.24; 1.72)	-
Birth weight (g)	3,152.51 (552.26); 500 a 5,990[b]					
500 to 1499	1,795 (1.30)	1,208 (0.88)	587 (52.13)	327.02	328.91 (268.96;402.24)	41.15 (29.25; 57.87)
1500 to 2499	11,179 (8.09)	10,910 (7.96)	269 (23.89)	24.06	16.69 (13.49;20.65)	5.46 (4.07;7.31)
2500 to 2999	33,990 (24.60)	33,863 (24.71)	127 (11.28)	3.74	2.54 (1.98;3.25)	1.97 (1.50;2.58)
3000 to 3999	84,735 (61.32)	84,610 (61.74)	125 (11.10)	1.48	1	1
≥4000	6,474 (4.68)	6,456 (4.71)	18 (1.60)	2.78	1.89 (1.15;3.10)	1.43 (0.83;2.47)
1-minute Apgar score	8.29 (1.33); 0 a 10[b]					
9 or 10	73,385 (54.44)	73,271 (54.78)	114 (10.99)	1.55	1	1
7 or 8	52,344 (38.83)	52,107 (38.96)	237 (22.85)	4.53	2.92 (2.34;3.66)	1.59 (1.24;2.04)
<7	9,061 (6.73)	8,375 (6.26)	686 (66.15)	75.71	52.57 (43.06;64.18)	3.36 (2.44;4.61)
5-minute Apgar score	9.32 (0.88); 0 a 10[b]					
9 or 10	123,739 (91.70)	123,436 (92.19)	303 (29.19)	2.45	1	1
7 or 8	9,579 (7.10)	9,298 (6.94)	281 (27.07)	29.34	12.31 (10.45;14.50)	2.22 (1.74;2.84)
<7	1,615 (1.20)	1,161 (0.87)	454 (43.74)	281.11	158.95 (135.92;185.88)	11.39 (8.51;15.25)
Birth defects						
No	136,612 (99.19)	135,650 (99.29)	962 (86.51)	7.04	1	1
Yes	1,119 (0.81)	969 (0.71)	150 (13.49)	134.05	21.83 (18.17;26.22)	14.79 (11.18;19.59)
Simplified SGA						
Non-SGA	132,138 (95.88)	131,108 (95.91)	1,030 (92.29)	7.79	1	1
SGA	5,682 (4.12)	5,596 (4.09)	86 (7.71)	15.14	1.96 (1.57;2.44)	-
Place of birth						
Hospital	137,663 (99.46)	136,567 (99.49)	1,096 (96.99)	7.99	1	1
Other	740 (0.54)	706 (0.51)	34 (3.01)	45.95	6.00 (4.23;8.51)	-
Type of delivery						
Vaginal	76,550 (55.32)	75,888 (55.30)	662 (58.58)	8.65	1	1
Cesarean	61,816 (44.68)	61,348 (44.70)	468 (41.42)	7.57	0.87 (0.78;0.98)	0.80 (0.68;0.93)
Type of pregnancy						
Single	135,751 (98.12)	134,720 (98.17)	1,031 (91.32)	7.59	1	
Multiple	2,605 (1.88)	2,507 (1.83)	98 (8.68)	37.62	5.11 (4.14;6.31)	-
Gestational age (weeks)						
≥37	126,578 (91.73)	126,251 (92.25)	327 (29.20)	2.59	1	1
<37	11,406 (8.27)	10,613 (7.75)	793 (70.80)	69.44	28.85 (25.32;32.86)	1.84 (1.42;2.39)
Prenatal visits						
≥7	81,944 (59.52)	81,593 (59.75)	351 (31.71)	4.28	1	
1 to 6	52,152 (37.88)	51,519 (37.72)	633 (57.18)	12.14	2.86 (2.51;3.26)	-
None	3,579 (2.60)	3,456 (2.53)	123 (11.11)	34.37	8.27 (6.72;10.19)	-

To be continued

Table 1 continuation

Variables	Live births (%)	Survival (%)	Death (%)	Neonatal mortality rate (1000)	Crude OR (95% CI)	Adjusted OR[a] (95% CI)
Parity						
≤ 2	106,630 (83.53)	105,813 (83.58)	817 (78.33)	7.66	1	
> 2	21,020 (16.47)	20,794 (16.42)	226 (21.67)	10.75	1.41 (1.21;1.63)	-
Previous fetal loss						
No	118,019 (92.33)	117,096 (92.37)	923 (88.33)	7.82	1	1
Yes	9,801 (7.67)	9,679 (7.63)	122 (11.67)	12.45	1.60 (1.32;1.93)	1.29 (1.01;1.65)
Mother's age (years)						
20 to 34	92,589 (66.95)	91,871 (66.98)	718 (63.54)	7.75	1	
≥35	19,218 (13.90)	19,063 (13.90)	155 (13.72)	8.07	1.04 (0.87;1.24)	-
<20	26,487 (19.15)	26,230 (19.12)	257 (22.74)	9.70	1.25 (1.09;1.45)	-
Maternal education (years of schooling)						
12 or more	21,054 (15.30)	20,915 (15.33)	139 (12.43)	6.60	1	
4 to 11	104,328 (75.84)	103,474 (75.84)	854 (76.39)	8.19	1.24 (1.04;1.49)	-
0 to 3	12,182 (8.86)	12,057 (8.84)	125 (11.18)	10.26	1.56 (1.22;1.99)	-
Marital status						
Married	52,713 (38.23)	52,370 (38.29)	343 (30.60)	6.51	1	
Other	85,172 (61.77)	84,394 (61.71)	778 (69.40)	9.13	1.41 (1.24;1.60)	
Mother's occupation						-
Homemaker	76,621 (59.66)	75,948 (59.62)	673 (64.53)	8.77	1	
Other	51,814 (40.34)	51,443 (40.38)	371 (35.47)	7.16	1.23 (1.08;1.40)	-

n = 138,407; 95% CI: 95% confidence Interval
aAdjusted for other variables in the table by traditional multiple logistic regression models
b Mean (standard deviation); minimum–maximum, missing information (n;% of total) and excluded from the analysis: gender (6; 0.00), skin color/ethnicity (256; 0.18), birth weight (234; 0.17), 1-minute Apgar score (3,617; 2.61), 5-minute Apgar score (3,474; 2.51), birth defect (676; 0.49), simplified SGA (587; 0.42), place of birth (4; 0.00), type of delivery (41; 0.03), type of pregnancy (51; 0.04), gestational age (423; 0.31), prenatal visits (732; 0.53), parity (10,757; 7.77), previous fetal loss (10,587; 7.65), mother's age (113; 0.08), education (843; 0.61), marital status (522; 0.38), occupation (9,973; 7.20)

of epidemiological information on births. SINASC database has good-to-excellent data completeness and shows good consistency for most variables despite data completion problems.[19]

The analysis of this cohort showed that the neonatal mortality rate was about half of the national average rate in 2003, which is still high compared to rates in developed countries. Higher rates of early neonatal deaths are corroborates in other studies.[12,22] This proportional increase may be explained by a decline in late neonatal and post-neonatal mortality rates that have been reduced through simple interventions such as immunization and oral rehydration therapy.[25]

Birth weight and prematurity are major risk factors for neonatal mortality.[3,7,11,18] In the present study, there was found an inverse relationship between birth weight and neonatal death, consistent with other studies conducted in Pelotas (Southern Brazil), São Paulo (Southeastern Brazil), and Recife (Northeastern Brazil).[3,12,22] Pre-term newborns were almost twice as likely to die in the neonatal period compared with full-term infants, as reported in a study conducted in São Paulo.[12]

Although Brazilian studies have reported an association between increased neonatal mortality and cesarean sections,[16] the present study found that cesarean births had a protective effect, especially for preterm newborns. Early elective delivery with adequate indication for a cesarean section may reduce the risk of death for preterm newborns at risk, i.e., the risk of waiting for natural childbirth may exceed that of cesarean delivery. A study in the city of Goiânia, Central-West Brazil, has investigated this effect and pointed out that birth in a hospital that is not affiliated to the Sistema Único de Saúde (SUS – National Health System), where cesarean rates are higher, may be associated with higher socioeconomic conditions and maternal health status.[16] Furthermore, cohort studies conducted in Montes Claros, Southeastern Brazil, and Recife found no significant association between type of delivery and neonatal death.[14,22]

Table 2. Risk factors for neonatal mortality for preterm and full-term newborns. Rio Grande do Sul, Southern Brazil, 2003.

Variables	Preterm n = 11,406 (8.24%)		Full-term n = 126,578 (91.45%)	
	Crude OR	Adjusted OR[a] (95% CI)	Crude OR	Adjusted OR[a] (95% CI)
Birth weight (g)				
≥2500	1	1	1	1
<2500	16.06	7.67 (5.17;11.38)	7.78	4.07 (3.00;5.50)
1-minute Apgar score				
9 or 10	1	1	1	1
7 or 8	2.63	1.77 (1.23;2.54)	1.77	1.36 (0.98;1.89)
<7	24.42	3.96 (2.63;5.97)	22.22	3.72 (2.35;5.89)
5-minute Apgar score				
9 or 10	1	1	1	1
7 or 8	5.24	2.11 (1.61;2.76)	7.31	2.81 (1.88;4.20)
<7	45.92	11.16 (8.13;15.32)	100.60	23.20 (14.67;36.68)
Birth defect				
No	1	1	1	1
Yes	8.41	4.51 (3.02;6.72)	46.01	21.81 (15.60;30.50)
Type of delivery				
Vaginal	1	1		
Cesarean	0.64	0.74 (0.62;0.89)	-	-
Prenatal visits				
≥7	1	1		
1 to 6	2.33	1.43 (1.17;1.75)	-	-
None	5.22	1.99 (1.42;2.79)	-	-

[a] Adjusted for other variables in the table through traditional multiple logistic regression models.

There was found an association between Apgar scores and neonatal mortality, especially for 5-minute Apgar scores, which corroborates studies conducted in São Paulo,[13] Montes Claros[14] and Recife.[18] Unlike most Brazilian studies[22,24] who found scores <7 as predictive of increased risk of death, the present study showed that Apgar scores ≤8 indicated more vulnerable newborns.

Birth defects and previous fetal loss – variables not explored in most studies – were associated with the outcome. This association has been reported in a study conducted in São Paulo, although stronger than that observed in the present analysis.[2]

The literature points to the importance of the determinants investigated in traditional analysis; many health processes result from factors that are affected at different levels because they share the same environment or have similar characteristics. Thus, the individuals involved may be correlated, and violation of the assumption of independence of observations may lead to biased estimates while using traditional regression techniques.[9]

The ability to estimate the variability at each level is one of the main strengths of multilevel models.[9] In the present study there was seen greater effect of individual factors and a smaller though significant effect of microregions. A Canadian study has suggested that the effects of local distribution of health problems in large administrative areas are relatively small and influenced by the size of the geographical area and the selected health indicator.[5]

A comparison of estimates from the traditional and the multilevel model showed that standard errors were, on average, one percent point higher in the multilevel model, which can be considered a small difference. It was found that the odds of dying in the neonatal period were greater for children born in microregions with higher poverty rate in the general model. However, the size of geographical areas or limited availability of variables may not have allowed to identifying a stronger effect at the upper level. A study evaluating child mortality trends in Porto Alegre reported smaller reductions in poorer areas; however, it did not include a multilevel analysis.[8]

A cohort study of 223,289 live births and 1,266 child deaths in the state of New York, US, included multilevel logistic regression analysis to identify individual and contextual (counties) determinants of child mortality. The poverty had no significant effect. Government spending on health services and hospitals were associated with increased likelihood of child mortality, while high number of hospital beds per capita reduced the likelihood of death. As in the present study, the New

Table 3. Risk factors for neonatal mortality due to all causes, in the general model and for preterm newborns. Rio Grande do Sul, Southern Brazil, 2003.

Variables	General		Preterm	
	Model 1 OR[a] (95% CI)	Model 2 OR[a] (95% CI)	Model 1 OR[a] (95% CI)	Model 2 OR[a] (95% CI)
Individual-level effect				
Birth weight (g)				
500 to 1499	43.82 (31.40;61.14)	44.26 (31.72;61.76)	-	-
1500 to 2499	5.75 (4.32;7.66)	5.75 (4.32;7.66)	-	-
2500 to 2999	1.99 (1.53;2.60)	1.99 (1.53;2.60)	-	-
3000 to 3999	1	1	-	-
≥4000	1.58 (0.94;2.65)	1.57 (0.93;2.65)*	-	-
Birth weight (g)				
≥2500	-	-	1	1
<2500	-	-	7.61 (5.10;11.36)	7.61 (5.10;11.36)
1-minute Apgar score				
9 or 10	1	1	1	1
7 or 8	1.55 (1.22;1.98)	1.54 (1.21;1.97)	1.74 (1.21;2.51)**	1.75 (1.22;2.53)
<7	3.19 (2.34;4.35)	3.19 (2.34;4.35)	3.94 (2.60;5.96)	3.97 (2.62;6.02)
5-minute Apgar score				
9 or 10	1	1	1	1
7 or 8	2.24 (1.76;2.84)	2.24 (1.76;2.84)	2.11 (1.61;2.78)	2.11 (1.61;2.78)
<7	11.70 (8.81;15.55)	11.70 (8.81;15.55)	11.47 (8.62;15.82)	11.47 (8.3215.82)
Type of delivery				
Vaginal	1	1	1	1
Cesarean	0.83 (0.72;0.97)	0.84 (0.72;0.98)**	0.77 (0.64;0.92)	0.76 (0.63;0.92)
Gestational age (weeks)				
≥37	1	1	-	-
<37	1.84 (1.43;2.37)	1.84 (1.43;2.37)	-	-
Birth defect				
No	1	1	1	1
Yes	15.03 (11.45;19.74)	15.03 (11.45;19.74)	4.81 (3.21;7.20)	4.81 (3.21;7.20)
Prenatal visits				
≥7	-	-	1	1
1 to 6	-	-	1.48 (1.20;1.82)	1.49 (1.21;1.83)
None	-	-	2.16 (1.53;3.05)	2.15 (1.53;3.03)
Hierarchical effect				
Variance at level 1 (σ^2_{eo})	1	1	1	1
Variance at level 2 (σ^2_{uo})	0.111 (0.02;0.20) p = 0.016	0.094 (0.02;0.17) p = 0.023	0.135 (0.02;0.25) p = 0.024	0.107(0.01;0.21) p = 0.041
Poverty rate (percentage of people with *per capita* household income less than half the minimum wage)	-	1.47 (1.08;2.00) p = 0.015	-	-
Water supply (proportion of households with water supply system)	-	-	-	0.69 (0.50;0.96) p = 0.028
DIC	6,400.35	6,399.41	3,357.78	3,557.24

DIC: Bayesian deviance information criterion

[a] Adjusted for other variables in the table using multilevel multiple logistic regression models

* p = 0.090, ** p = 0.025; Other: p<0.01; Model 1: Individual-level variables; Model 2: Individual-level and contextual variables.

York study tested other variables but they were not associated with outcome, although it did not include birth weight and gestational age as exploratory variables.[15]

Two studies carried out in Northeast Brazil used multilevel proportional hazards models for child survival analyzed at household and municipality level. One study[23] found non-significant variance at the household level but significant variance at the municipality level. Birth interval and birth order were major predictors of child mortality, as well as mother's education and family income, though with lower effect.[23] The second study showed that prenatal care, higher maternal education, Caucasian or Asian ethnicity and having a refrigerator at home are factors that reduce the risk of child death. It was also found an association with birth order and birth interval, but not with the municipality where children lived.[21]

In multilevel models, residuals can be analyzed at each level, enabling to assess specific patterns in the areas studied.[9] The microregion of Porto Alegre had a lower than average risk of neonatal death, possibly due to increased access to quality care. On the other hand, the microregions of Passo Fundo and Litoral Lagunar had a higher than average risk in the general model, indicating the need for specific actions in these areas, such as quality prenatal, delivery and newborn care.

One of the limitations of the study is that there may have been measurement bias due to the use of secondary data, the effect of the size of microregions (large internal variability) and non-inclusion of other potential determinants such as alcohol and tobacco use or breastfeeding (data not available), as well as the classification used for errors in the records.

Due to the large number of variables studied and the correlation between some of them, the explanatory power of other variables not included would likely be reduced. This could in part explain the small effect of area as the intra-unit correlation is inversely associated to the size of the groups.[5] On the other hand, smaller groups could negatively affect the results because of the large number of localities with a small number of events.

The bias of the ecological fallacy – all observations in a given area hold to all individuals within that area – should also be considered.

Multilevel models do not necessarily produce results different from the traditional statistical analysis, but the estimates tend to be more accurate. Despite its limitations, multilevel modeling was able to capture a significant effect at each level.

This is the first study of neonatal mortality determinants carried out using a multilevel analysis technique in Brazil. The multilevel models revealed small differences from the traditional analysis in terms of model fitness and the magnitude of estimated effects. The power of this analysis outweighs the methodological difficulties, especially in the study of pooled data.

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