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Maternal characteristics and the risk of neonatal mortality in Brazil between 2006 and 2016

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Abstract: Neonatal deaths account for more than 60% of infant deaths and are a major concern in Brazil. The reduction of the occurrence of these events appears to be more challenging than post-neonatal deaths, as such a reduction depends more on factors related to the pregnancy and childbirth than sanitary and health conditions. The aim of the present study was to evaluate the influence of maternal factors (schooling, marital status, and age) on the risk of neonatal mortality in Brazil between 2006 and 2016. Data were collected from the Brazilian Institute of Geography and Statistics as well as two information systems of the public health-care system: Mortality Information System and Live Birth Information System. The total valid sample size was 28,362,359 children. Visualization and classification methods were performed. The results revealed a considerably higher risk of neonatal deaths when the mothers were unmarried, had a low level of schooling, and were outside the 20-34-year-old age group. Different demographic profiles in Brazil exert an influence on neonatal health. The identification of the risk factors of neonatal mortality can assist in ensuring pregnancy, delivery, and a neonatal period of greater quality.

Keywords: Infant mortality; Neonatal mortality; Maternal age; Risk factors; Brazil

1. Introduction

The infant mortality rate (IMR) is considered one of the best indicators of a population's standard of living and social well-being. The decline in this rate constitutes a remarkable success of governments, civil society, and academia and health professionals in the past two centuries. Global mortality has declined 5 times in the past 65 years, reaching 4.5% in 2015. Particularly in Brazil, the reduction was greater than 10 times in the same period (World Bank, 2019). Nonetheless, disparities between developed and developing countries demonstrate that there is much work left to do. The fact that mortality rates in developing countries can be 10 times higher than those in developed countries is proof that we are dealing with a high percentage of avoidable deaths.

A reduction in child mortality rates is listed as one of United Nations (UN) Sustainable Development Goals for 2030 (UN Resolution, 2015) and was also listed as one of UN's Millennium Development Goals for 2015, which aimed to reduce Child Mortality Rates by two-thirds between 1990 and 2015, a goal that Brazil achieved in 2011. The global IMR declined from 65 deaths per 1000 live births in 1990 to less than 30 by 2018, which is a considerable improvement, but still far from the rate considered acceptable by the World Health Organization (WHO), which is 12 neonatal deaths per 1000 live births by 2030.

This will be significant, as almost half of these under-five deaths are newborns whose deaths can be prevented through higher coverage of quality prenatal care, skilled care at birth, postnatal care for both the mother and infant and the care of small, sick newborns (UN IGME, 2019), that is, conditions that could be prevented or treated with access to simple, low-cost interventions. These avoidable deaths are one of the focuses of the UN goals for 2030 (WHO, 2020; ODS, 2020; Golding *et al.,* 2017).

Monitoring infant mortality and associated risk factors are essential to evaluating public policy and development. This measure is a strong indicator of socioeconomic conditions, such as poverty, access to education and health services (Gaiva, Fujimori and Sato, 2015; Carvalho *et al.,* 2020). A study on the determinants of infant mortality can be of considerable help to the better targeting of public policy funding, which is increasingly possible through online platforms that make data available, such as DATASUS, which is a Department of Brazilian Health Ministry responsible for collecting, processing, and disseminating public health data.

In Brazil, the IMR has undergone a continual decrease in the recent decades, mainly due to the reduction in post-neonatal deaths (those occurring between 28 days and 1 year) and improvements in sanitary conditions. The share of post-neonatal deaths among total infant deaths declined from 51% in 1990 to 38% in 2015 (IGME, 2020). Neonatal mortality (deaths occuring less than 28 days), which is the main component of the IMR in Brazil, has also been following a declining trend, mainly due to favorable changes in factors related to pregnancy and childbirth, despite the increase of its shared proportion. Neonatal mortality is harder to address and extends to the perinatal period (Duarte, 2007; Carvalho *et al.*, 2020). Indeed, neonatal mortality has become the biggest challenge in fighting infant mortality, as it currently corresponds to the majority of such deaths and involves various biological, socioeconomic, and health-care factors. Neonatal mortality rates (NMR) have decreased but have also become the focus of public policies on infant mortality due to its proportion of the global IMR. The greater availability and the quality of health data in Brazil have enabled more precise analyses of this issue on a nationwide scale. This availability of data and the increasing importance of neonatal deaths on infant mortality have led to a significant number of studies covering different factors, regions, and methods concerning neonatal deaths.

The aim of the present study is to investigate the maternal factors associated with neonatal mortality by employing the framework proposed by Mosley and Chen (2003), using a hierarchical model based on the hypothesis that socioeconomic factors determine behaviors that exert an impact on biological factors. In their influential paper, Mosley and Chen argue that mortality studies usually have a bias toward the social or biological approach, isolating the external determinants according to the field of study. Therefore, even if biological factors are directly responsible for deaths, this information may be insufficient regarding the establishment of adequate recommendations and effective public policies. Maternal characteristics also have the advantage of being available earlier compared to childbirth or pregnancy-related factors. Moreover, some studies have shown the predictive power of these factors in affecting the IMR (Fonseca, Flores, Camargo Jr. *et al*., 2017; Bertoldi *et al*., 2019).

This study offers an analysis and discussion of neonatal mortality in Brazil considering a broader perspective available through a nationwide sample, using data visualization techniques and classifications to summarize the results. The aim is to help predict the risk of neonatal mortality in Brazil by evaluating important characteristics related to the mother and considering the period between 2006 and 2016.

2. Materials and Methods

An observational, retrospective, and cohort study was conducted with secondary data on births and deaths of infants in Brazil between 2006 and 2016. Data were obtained from two sources: *Sistema de Informação sobre Mortalidade* (SIM [Mortality Information System]) and *Sistema de Informação sobre Nascidos Vivos* (SINASC [Live Birth Information System]), both of which are available through DATASUS (Health Informatics Department of the Brazilian Ministry of Health) and the *Instituto Brasileiro de Geografia e Estatística* (IBGE [Brazilian Institute of Geography and Statistics]). Figure 1 illustrates the linkage process between the two datasets (SIM and SINASC) concerning the characteristics selected for this study as well as the data selection process. The main problem is the availability of a standard variable between the two datasets to enable successful merging. The standard variable Declaration of Live Birth Number (NUMERODN) was only available in 36.5% of the cases (197,971 out of 543,437 deaths), despite the fact that filling in this information is mandatory. From this percentage, it was possible to link 95% of the cases, resulting in a large dataset. Some entries were also excluded due to inaccurate data (such as extreme outliers of age – above 90 years). The final sample was 28,362,359 children, representing 151,473 neonatal deaths records. Moreover, the datasets are unbalanced, i.e., the percentage of death class samples outnumbers the percentage of living class samples.

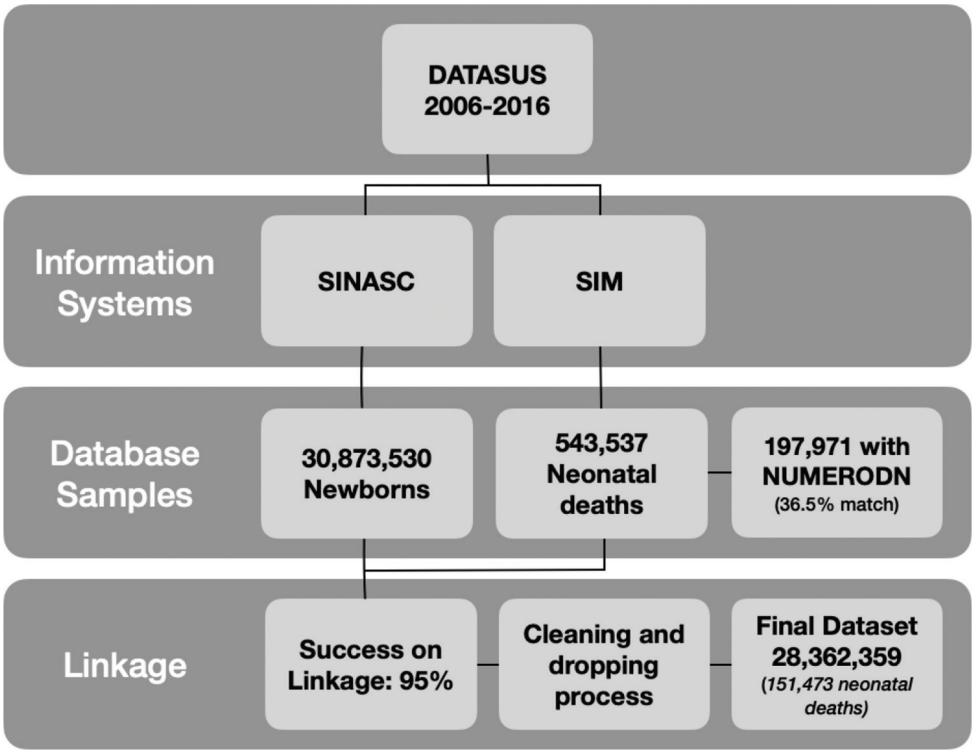

Figure 1. Flowchart of linkage process with data from SIM and SINASC, Brazil.

For the present investigation, we considered the following maternal characteristics: age (10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50, or more years), schooling (0, 1-3, 4-7, 8-11, 12, or more years of study), marital status (single, married/stable relationship, widowed, and separated/divorced), and race/skin color (white, black/brown, and yellow/indigenous). About 50% of newborns had missing data on race/skin color and were therefore excluded from the analysis.

Descriptive statistics were performed for all variables analyzed in the study. The NMR was estimated by dividing the number of deaths of infants less than 28 days of age by the number of live births per 1,000. Decision trees constitute a method for identifying homogenous subgroups of the population. As only three categorical variables were used in the present study, we created three decision trees through a descriptive analysis between the NMR and the following combinations: marital status and years of schooling, age and marital status, and years of schooling and age. Each of the visualizations enables identifying the relationship between a variable and the NMR and the relationship between two variables combined and the NMR, resulting in a more specific classification. The other visualization methods used were line graphs, bar plots, and boxplots.

The methods used to treat the data and produce visualizations were the Python programming language (3.6) along with the Pandas, Matplotlib, and Seaborn modules. LibreOffice Calc and Google Drawings were used for the displays.

3. Results

Between 2006 and 2016, a considerable decrease in infant mortality occurred in Brazil. However, while the post-neonatal mortality dropped by 27%, neonatal mortality decreased by only 20% in the same period, reaching the nine deaths per every 1,000 births, as shown in Figure 2.

Figure 3 shows the descriptive characteristics of births in Brazil between 2006 and 2016 and the NMR according to mother's age, schooling, and marital status. Most mothers had 8-11 years of schooling (50.5%) and, despite the difference, mortality rates were similar for mothers with 1-11 years of schooling, whereas mortality rates decreased notably when mothers had 12 or more years of schooling, which corresponded to 16.2% of the sample. Although a small part of the population (1.3%), mothers with no education had a much higher risk of losing their infants in the first 28 days, with a rate at least 18% higher in comparison to the other groups.

In the dataset, the percentage of missing data on marital status was less than 2%. Unmarried women surpassed married women and those in a stable relationship, accounting for 61.2% of the total. The risk of neonatal mortality was lower when the mothers were married or in a stable relationship.

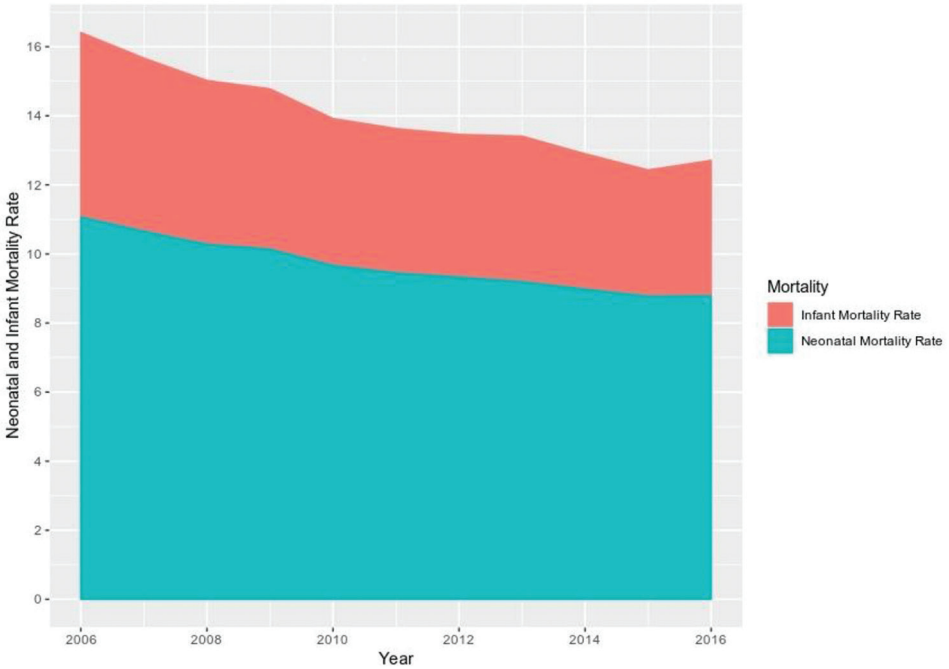

Figure 2. Neonatal mortality rate and infant mortality rate, Brazil, 2006-2016. Source: IBGE (2006-2016).

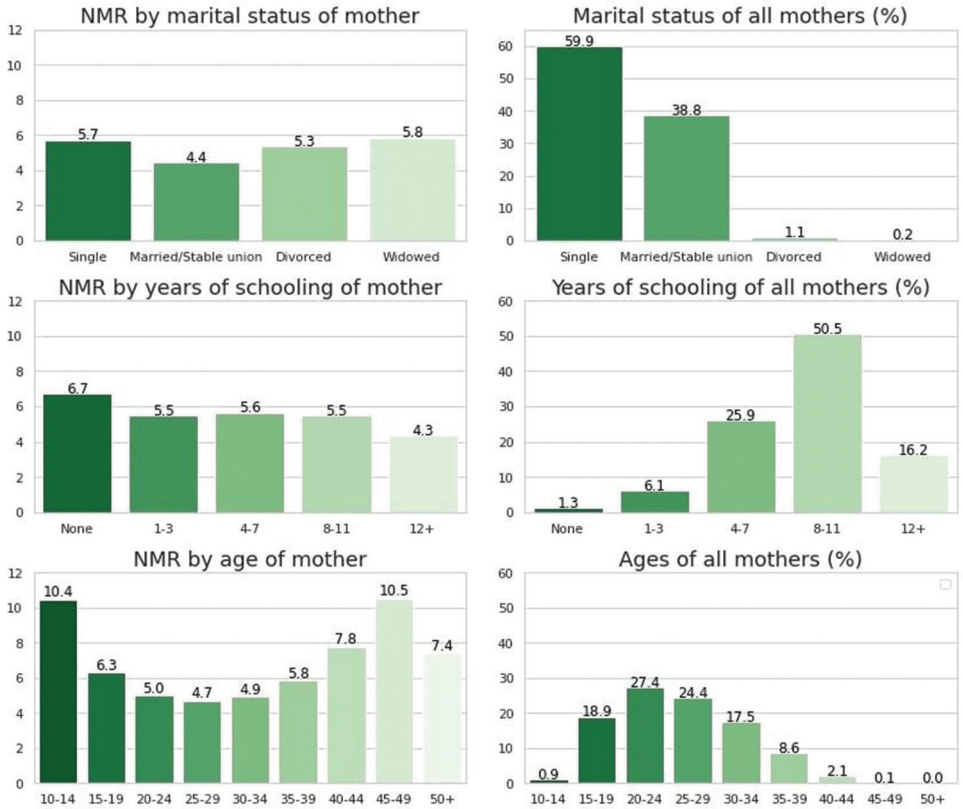

Figure 3. Neonatal mortality rate and descriptive characteristics of births according to mother's age, schooling, and marital status, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016. NMR: per 1,000.

Most births (69.3%) were concentrated in the 20-34 years old age and the risk of neonatal death was lower in this group. The lowest NMR was found in the group of mothers between 25 and 29 years of age. The choice of having children later in life due to cultural and career changes in the lives of women has pushed the average age of childbirth higher. Mothers less than 15 years of age and those older than 40 years had the highest risks of neonatal mortality.

The boxplot on Figure 4 shows how the standard deviation is increased in the neonatal death group, even though the large amount of women 20-34 years of age strongly pushes the average to a center and the deviation to a smaller range. As 69.3% of the mothers were between 20 and 34 years old, the standard deviation shift is high. No differences were found in median age and mean age between the neonatal death group and the all mothers group.

The last visualizations (Figures 5) are three decision trees (James, Witten, Hastie *et al.*, 2003). The middle boxes contain the NMR and the percentage of the group within the sample. The node boxes on the right contain only the NMR for each combined feature. The results reveal higher NMRs among older mothers, unmarried mothers, and those with no schooling compared to mothers younger than 35 years of age, married mothers, and those with 12 or more years of schooling. The NMR was 17% higher among unmarried mothers compared to married mothers. In the analysis of combined features, the NMRs were higher among older mothers even when they had a higher level of schooling. These higher rates among older mothers were similar to those found among younger mothers with no schooling, suggesting an important influence of extremes of age on neonatal mortality in Brazil. In the analysis of marital status and mother's age, higher NMRs were found among older (35 years or more) unmarried mothers. The NMR was also high in youngest group (10-19 years of age) and this result was more unfavorable among unmarried mothers. Indeed, the NMR was higher among unmarried mothers in all age groups. In the analysis of schooling and marital status, higher NMRs were found among married and unmarried mothers without schooling, with higher rates found among the married mothers. The lowest NMR (4.16) was found among married mothers with 12 or more years of schooling. The majority of mothers (82.1%) had between 1 and 11 years of schooling. In this group, the NMR was lower among the married mothers (5.31) compared to unmarried mothers (6.0). This decision tree also showed that the mothers with no schooling only accounted for 1.3% of the sample. Although this proportion is small, it represents nearly 2,600 neonatal deaths.

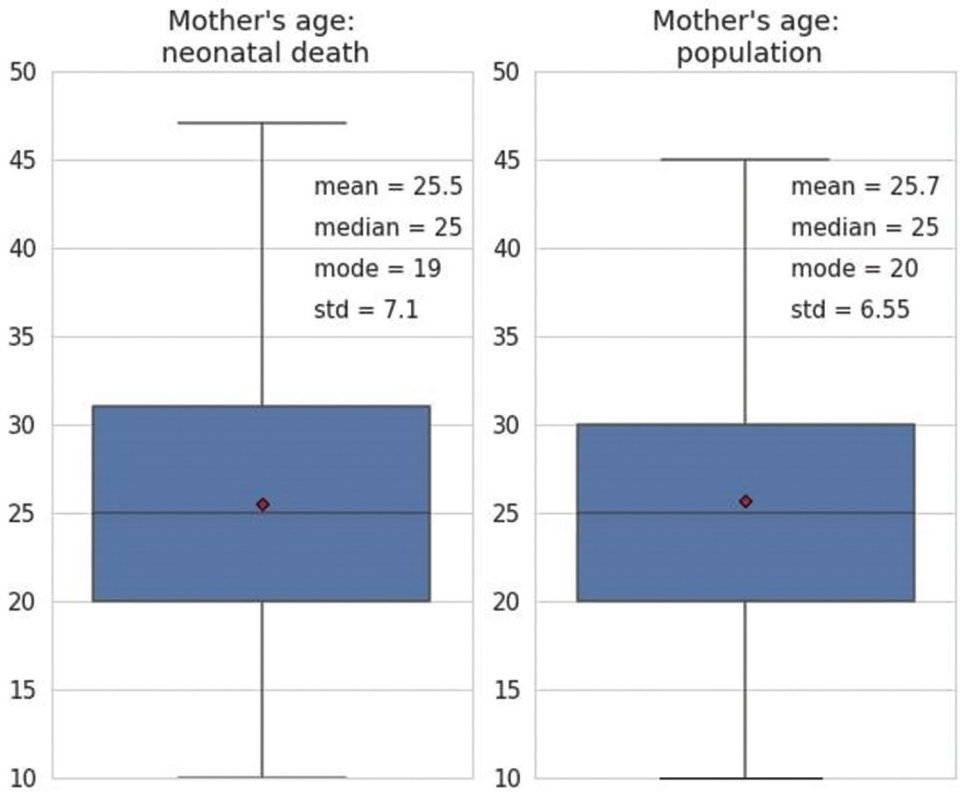

Figure 4. Boxplots of the mother's age at childbirth, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016.

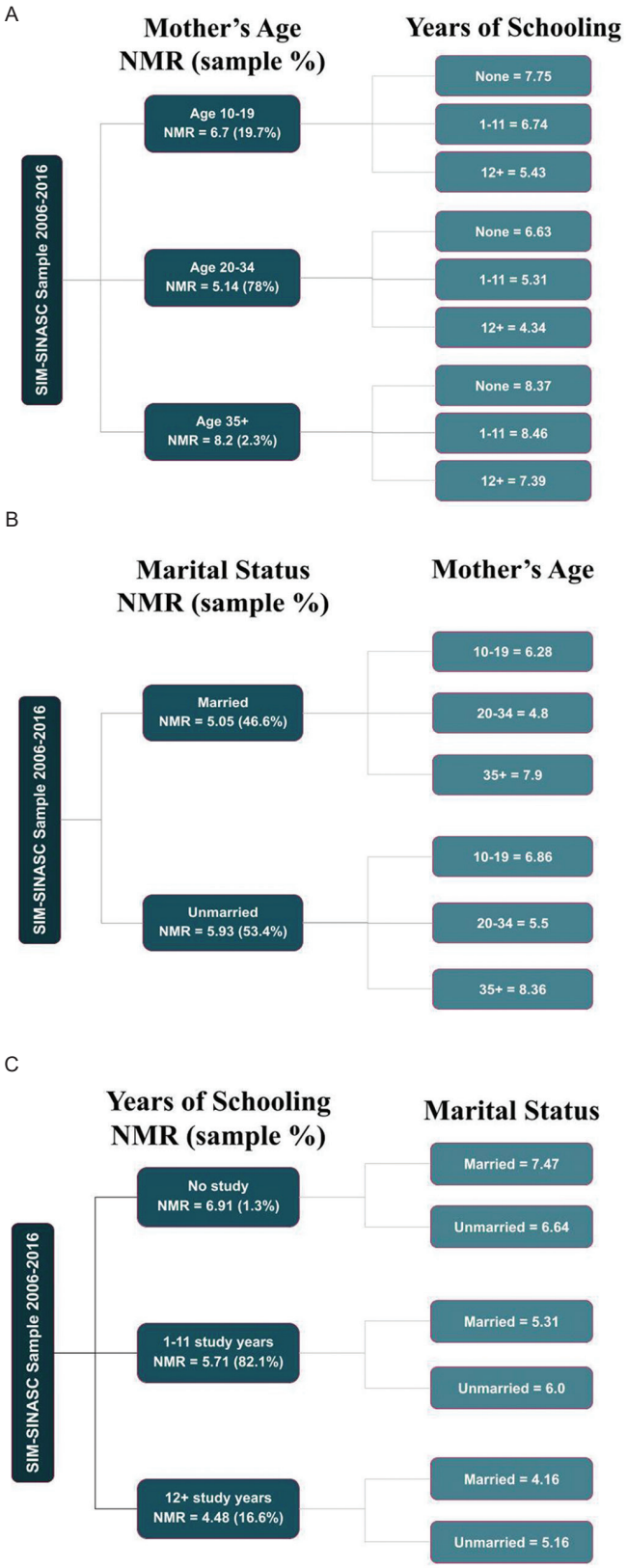

Figure 5. (A-C) Decision trees combining neonatal mortality risk for years of schooling, age, and marital status, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016.

4. Discussion

In this study, we examined the risk of neonatal mortality according to the maternal characteristics in Brazil between 2006 and 2016. Using the decision trees, we measured the effect of different characteristics on the NMR. Combining two different determinants makes disparities in NMR more evident. This classification enables us to offer specific solutions according to the characteristics of each group in addition to contributing to better monitoring of the effect of each determinant. The lowest NMR were found when mothers were 20-34 years of age and had 12 or more of schooling. In contrast, high rates were found when mothers had no education, were unmarried, and were older than 34 years of age. When combined, these factors compose the highest risk groups.

The previous studies have assessed the importance of maternal characteristics in the distribution of neonatal mortality using local samples. The present study is an effort to provide new information in this direction. According to Flenady (2015), most neonatal deaths in developing countries could be prevented with better care during pregnancy, since many are due to inadequate health care for the mother before birth, as shown by Gaiva, Fujimori and Sato (2015) in Brazil. The features selected in the present investigation are available at the onset of a pregnancy and can help detect such cases more quickly.

The results concerning mother's age confirm the findings of the previous investigations. Some studies report strong evidence for both socioeconomic and biological issues concerning the risk of infant death among adolescent mothers (Fonseca, Flores, Camargo Jr. *et al.,* 2017; Oliveira, Gonçalves, Costa *et al.,* 2016; Teixeira *et al.,* 2016). In Brazil, the pregnancy rate among adolescents has generally declined in recent decades, although levels remain high (UNFPA, 2018). Adolescent pregnancies are more likely to occur in marginalized communities, which are commonly characterized by poverty as well as lack of education and employment opportunities (UNICEF, 2013), leading to an increased risk of infant mortality (Oliveira, Gama and Silva, 2010). According to César, Ribeiro and Abreu (2000), the difference found in the mortality of children of adolescent mothers may reflect the poverty effect more than the age effect and is also an indicator of the precariousness or even lack of adequate prenatal care.

While the average age of mothers at childbirth has decreased in Latin America to around 20-24 years old in the past decade, the average age in developed countries had increased significantly to above 28 years. Mothers older than 35 years of age tend to have a better education, a planned pregnancy and better care in terms of both medical and emotional aspects. However, they face challenges due to their older age. Age is related to an increase in the incidence of diseases such as diabetes and hypertension, both of which are associated with higher infant mortality risk (Jahromi and Husseini, 2008; Dietl, Cupisti, Beckmann *et al.*, 2015; Oliveira, Gonçalves, Costa *et al.,* 2016; Vidal *et al.*, 2018).

Education provides several health advantages because it exerts a positive influence on psychosocial and behavioral factors. The results of the present investigation are in agreement with data described in the previous studies (Fonseca, Flores, Camargo Jr. *et al.,* 2017; Oliveira, Gonçalves, Costa *et al.,* 2016), which report that mothers with 10 or more years of schooling have half the risk of losing their babies in the 1st month than mothers with 1-4 years of schooling, whereas women with no schooling have a higher risk of NMR compared to women with schooling. Teixeira *el al.* (2016) found that more than 8 years of mother's schooling were a protective factor, exerting positive effect on the reduction in infant mortality. In the present investigation, the risk of neonatal mortality was significantly higher among mothers with no schooling. Fonseca, Flores, Camargo Jr. *et al.* (2017) found that children of mothers with less than 4 years of schooling had a greater chance of neonatal death compared to the children of mothers with at least 4 years of education. The authors report that the ability to acquire knowledge on health issues and the optimal use of health services are attributed to a higher educational level. The ability to assess the onset of symptoms properly is also correlated with education.

Many changes have occurred in recent decades. Access to information and the standardization of health-care protocols has diminished the impact of mother's schooling on the life outcome. However, this variable has an explanatory power that needs to be better distinguished from its correlation to wealth and the availability of health-care services. The present study confirms a trend found in recent research. Fonseca, Flores, Camargo Jr. *et al.* (2017) investigated data from the state of Rio de Janeiro between 2004 and 2010 and found that NMR was reduced at a lower rate among mothers with fewer years of schooling and that there was no reduction in the NMR among mothers with no schooling.

Marital status is the least studied factor in terms of infant mortality. Most studies often distinguish this variable into two major groups (married and unmarried). According to DeRose, Salazar-Arango, García *et al.* (2017), unmarried mothers in the Global South are younger, have less schooling and a lower socioeconomic status compared to the married mothers. A systematic review and meta-analysis of neonatal mortality risk factors in Brazil were

recently published (Veloso, Kassar, Oliveira, *et al*., 2019) and show that mother's age above 35 years and the absence of a partner are the most significant predictors of neonatal death. This confirms the results found in the present study, but the study by Veloso, Kassar, Oliveira *et al*. did not consider the role of education in reducing mortality rates.

The inadequate quality and availability of data persist as a significant barrier to a better understanding of neonatal mortality in Brazil, as the most vulnerable places are also those with the weakest data reporting (Maia, Souza and Mendes, 2015; Morais and Costa, 2017; Szwarcwald *et al.,* 2019). The inadequate quality of the data affects the accuracy of the results, such that this extensive database must be analyzed as a sample.

5. Conclusion

In the present study, we found that the risk of neonatal deaths was considerably higher among unmarried mothers with a low level of schooling as well as those outside the 20-34 years old age group, demonstrating that these features are relevant to the outcome. The investigation of maternal characteristics is crucial to accurate monitoring and ensuring continuity in the reduction of NMR in Brazil.

Throughout this work, we performed an exploratory analysis of data from the SIM and SINASC databases, resulting in graphical visualizations that enabled the evaluation of maternal characteristics from this quantitative perspective, along with the demographic, biological, and cultural elements developed in the discussion. However, this study has some limitations that should be considered. Although the dataset had nearly 30 million entries, problems related to the quality and consistency of the data impeded a perfect dataset linkage. Indeed, inadequate data quality and availability constitute a significant barrier. There were missing data on mother's race and the most vulnerable places have weak data coverage. Working with higher quality data and greater coverage is an open issue for further research that would enable more precision and the use of other technologies that require data on a specific condition or quantity, such as machine learning algorithms.

Infant and NMR are among the most important indices for gauging the overall level of public health as well as the social and economic development of a country or region (WHO, 1981). As Brazil has already achieved the Sustainable Development Goals (SDGs) for the reduction of infant and neonatal mortality established by the UN, new targets have been determined, such as an estimated NMR of 5.3 per 1,000 live births. The results of the present study confirm a trend in this direction and underscore the need to continue investing in actions aimed at combating preventable deaths through policies designed at reducing inequalities, expanding education, as well as the accessibility of effective health-care services to ensure a safe pregnancy for all ages and marital statuses. It is also important for Brazil to continue investing in public access platforms and the quality of information through a broadening of coverage for better guided decision-making.

Availability of Data and Materials Section

The dataset used in this paper is available at https://drive.google.com/drive/folders/19dFhQ8XEYzUBVYkqV9NKafxrKgWf5iOB?usp=sharing.

Authors' Contributions

PHC designed the study, performed the analysis, interpreted the data, and drafted the manuscript. LCA designed the study, interpreted the data, drafted, and revised the manuscript. CEB performed the analysis and revised the manuscript. NMA and RCB performed the analysis. TC designed the study, interpreted the data, and revised the manuscript. All authors read and approved the final manuscript.

Ethics

This paper uses publicly available data (SIM and SINASC) that has been de-identified and was deemed exempt from approval from a human research ethics committee.

Conflicts of Interest and Funding

All authors report no conflicts of interest. This research was supported by the Brazilian Ministry of Health through the National Council for Scientific and Technological Development (CNPq) (Process n: 443774/2018-8). It was also supported by NVIDIA, which donated a GPU XP Titan used by the research team.

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