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Spatial patterns of the total mortality over the first 24 hours of life and that due to preventable causes

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Abstract

This is an ecological study analysing spatial patterns of the total mortality over the first 24 hours of life and that due to preventable causes using data from the mortality information system (SIM) and live birth information system (SINASC) based on the municipalities of Pernambuco State, Brazil. The total mortality rates over the first 24 hours and that due to preventable causes were calculated for each municipality for the decades of 2000 to 2009 and for 2010 to 2019 to enable a comparison of the spatial patterns with spatial scan statistic used to identify clusters. Over the first 24 hours of life, a total of 13,571 deaths were reported, out of which 10,476 (77.2%) were preventable. The total mortality rate over the first 24 hours of life decreased from 5.5 in the 2000-2009 period to 3.7 per 1000 live births in the following decade: a reduction of 32.7%, while the mortality rate due to preventable causes decreased from 4.4 to 2.8 per 1000 live births, a reduction of 36.7%. In the first decade, spatial exploratory analysis found three mortality rate clusters encompassing 56 municipalities over the first 24 hours of life. With respect to preventable causes over the first 24 hours of life, two mortality rate clusters were identified encompassing 41 municipalities. Risk areas for mortality over the first 24 hours of life were detected through spatial scan statistic. This method, directed towards uncovering the geographical distribution of deaths of very premature infants, can act as a tool for identifying priority areas to guide healthcare interventions.

Introduction

The first month of life is regarded as the most critical for a child's survival: the closer the day of birth, the higher the risk of death and complications (Desalew *et al*., 2020). In 2019, 2,440,464 neonatal deaths occurred around the world, representing a mortality rate of 17.5 per 1000 live births (World Bank Group, 2021). Low-income countries and regions are those most affected by infant and neonatal mortality, and the proportion of deaths on the first day of life accounts for one in every three neonatal deaths in these locations (Baqui *et al*., 2016; Boutayeb *et al*., 2020).

In Brazil, 35,293 neonatal deaths were reported in 2019, out of which 8807 occurred over the first 24 hours of life. From this number, 6261 (71.1%) could have been avoided (Brazilian Ministry of Health, 2021). Deaths over the first 24 hours of life occur heterogeneously among the geographical regions of Brazil as a result of health disparities (Castro *et al*., 2016). The north-eastern region recorded the largest number of deaths (3020) in this age group in 2019. Out of this total, 482 (16%) were reported in the state of Pernambuco (Brazilian Ministry of Health, 2021). About 70% of the deaths that occurred in the early neonatal period could have been avoided through cost-effective healthcare measures, such as access to prenatal, medical appointments (Justino *et al*., 2019). Very early deaths are categorised as sentinel and potentially preventable events because they reflect the quality of the care provided through the healthcare system (Lohela *et al*., 2019).

The concept of preventability has emerged through observation of the growth of various technologies and the increasing numbers of professionals, especially physicians, in different healthcare services (Rutstein *et al*., 1976). In 2007, a list of causes of death that can be prevented through interventions within the National Health System (SUS) was prepared in Brazil. This systematized the concepts and methods for prevention after discussion within the healthcare specialities involved (Malta *et al*., 2007). In that list, causes of death were grouped as: preventable, ill-defined and other causes (not preventable) (Malta *et al*., 2007, 2010). The preventable causes, *i.e.* those that could be prevented through interventions within the healthcare system in the population under five years of age were grouped in the list as follows: reducible through immunoprevention; reducible through adequate delivery of care to women during pregnancy and at childbirth and to new-borns; reducible through appropriate diagnostic and treatment actions; and reducible through appropriate health promotion actions, linked to appropriate health care actions (Malta *et al*., 2007, 2010) (Supplementary material).

Incorporation of spatial analysis techniques into public health management helps detecting priority regions with higher risk of morbidity/mortality and/or areas with difficult access to healthcare (Tesema and Teshale, 2021). Thus, it directs planned investments into public policies toward maternal and child health (Weiland *et al*., 2021). The aim of this study was to analyse the spatial patterns of the total mortality over the first 24 hours of life, and that due to preventable causes in the state of Pernambuco, Brazil over the period 2000 to 2019.

Materials and methods

Study area

This was an ecological study in which the spatial analysis units were the municipalities of Pernambuco with a territorial area of 98,068.021 km² in Brazil's north-eastern region. Given that the municipality of the island of Fernando de Noronha is geographically separated from the continent, it was excluded from the analysis. In 2019, according to Brazilian Institute for Geography and Statistics (IBGE), the estimated population of Pernambuco was 9,557,071 people, 14,307 of whom less than one year old (IBGE, 2017). Healthcare in Pernambuco is organized in terms of 12 healthcare regions distributed among four macro-regions, namely: Macro-region 1 (Metropolitan), Macro-region 2 (Agreste), Macro-region 3 (Sertão) and Macro-region 4 (Vale do São Francisco and Araripe) (Pernambuco State Secretariat of Health, 2016) (Figure 1).

Data

The sources of data for this study were official, public domain systems of the Ministry of Health of Brazil. These systems are essential for management of healthcare services because they provide population data that enable delineation of epidemiological profiles (Pinto *et al*., 2018). The mortality information system (SIM) and the live birth information system (SINASC), for which data are available on the website of the Information Technology Department, the National Health System (SUS) (DATASUS) at

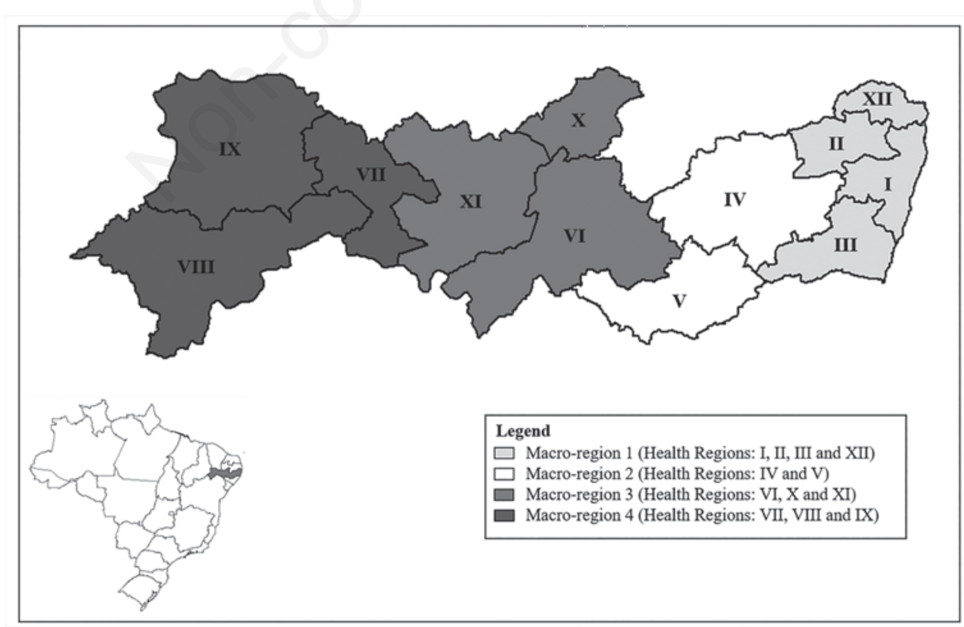

Figure 1. Location map of the state of Pernambuco and its division in macro-regions and healthcare regions. ***Source: Pernambuco State Health Department. Master Plan for Regionalization, 2011.***

https://datasus.saude.gov.br/, were used for the analyses of the present study (Brazilian Ministry of Health, 2021).

Approach

The total, crude mortality rates over the first 24 hours of life and those due to preventable causes were calculated for each municipality of residence per decade (2000-2009 and 2010-2019). At the municipal level, crude rates can be influenced by small areas/populations or by underreporting, which can generate random fluctuations in rates. To circumvent this behaviour, rate smoothing was adopted using the local empirical Bayesian method (Assunção *et al*., 1998).

Subsequently, scan statistic was used to detect clusters based on scanning the land area under analysis through an adjustable circular window with a radius that, in this study, aggregated a maximum of 10% of the population exposed (live births) (Kulldorf, 2021). For each circular window in the area analysed, the expected values are estimated as if the distribution of the event were homogeneous and compared with the values observed (Kulldorf, 2021). In regions with diverse values, clusters are formed with relative risk based on the relationship between observed and expected values, in addition to statistical significance (Kulldorf, 2021).

The digital municipal network for the state of Pernambuco was obtained from IBGE (2015). We used the QGIS software, version 2.14.18 (QGIS, 2021) and the SaTScan software, version 9.4.4 (SaTScan, 2016).

Results

The mortality rates over the first 24 hours of life were 5.5 and 3.7 per 1000 live births in the two decades studied (2000-2009 and 2010-2019), respectively. Thus, there was a decrease of 32.7%. The mortality rates due to preventable causes over the first 24 hours of life over the same periods were 4.4 and 2.8 per 1000 live births, which corresponds to a decrease of 36.7%.

Figure 2A and B show the mortality rates over the first 24 hours of life. It can be seen that the rates in 88 municipalities were lower in the second decade, *i.e*., these rates became less than 5.0 deaths per 1000 live births. A similar outcome was identified with regard to mortality due to preventable causes, in which the rates in 48 municipalities became lower (Figure 3A and B).

Although the number of municipalities with high mortality rates decreased, the scan analysis revealed that mortality continued to occur heterogeneously (Figures 2 and 3). The relative risk showed that, for both periods, there were areas with risks higher than 60% of the value expected for the Macro-regions of Agreste and Sertão (Table 1).

For the total mortality over the first 24 hours in the first decade studied, the scan analysis showed three clusters, which included 17.1% of all births in the state in this period and 22.1% of infant deaths. In one of these clusters, composed of 19 municipalities, almost all of which belonged to Macro-region 4 (Vale do São Francisco and Araripe), the relative risk of death was 40% higher than expected (Figure 2C and Table 1). With respect to the mortality due to preventable causes in the first decade, we noted two clusters encompassing 41 of the municipalities. The proportions of births and deaths over the first 24 hours for these clusters were 14.2% and 18.6%, respectively. The municipalities in the cluster with the higher relative risk of death due to preventable causes was 50% higher than expected and corresponded to the same municipalities in the cluster with the higher total mortality over the first 24 hours for the same period (Figure 3C and Table 1).

For the total mortality rate over the first 24 hours of life in the second decade, we detected four clusters that together encompassed 49 municipalities; the proportions of births and deaths were 17.9% and 26.4%, respectively. In a cluster of 17 municipalities, most of them in Macro-region 3 (Sertão), the relative risk of death was 70% higher (Figure 2D and Table 1). In relation to deaths due to preventable causes, four clusters encompassing 56 municipalities were detected, which represented 31.8% of total deaths and 20.8% of the total births. A cluster with 18 municipalities, belonging to Macro-regions 3 and 4, presented a 70% higher relative risk than expected regarding preventability (Figure 3D and Table 1).

The results showed that, for the two events analysed, there was a decrease from the first to the second decade. Among the deaths that occurred over in the first 24 hours, the proportion of preventable deaths was 77.2%. The clusters detected showed that for the mortality rates in the first 24 hours of life, in total and due to preventable causes, were higher than expected in most municipalities.

Table 1. Description of clusters of deaths over the first 24 hours of life, in total and due to preventable causes during 2000-2019 in Pernambuco, Brazil.

	Cluster	Number of municipalities	Deaths Observed	Deaths Expected	Relative risk	P-value (%)	Deaths (%)	Births
Total deaths over the first 24 hours of life (2000-2009)	1	19	681	487	1.4	0.0000	8.1	5.8
	2	12	496	375	1.3	0.0000	5.9	4.5
	3	25	678	573	1.2	0.0048	8.1	6.8
Total deaths over the first 24 hours of life (2010-2019)	1	17	369	230	1.7	0.0000	7.1	4.4
	2	16	394	254	1.6	0.0000	7.6	4.9
	3	4	346	257	1.4	0.0000	6.7	5.0
	4	12	260	189	1.4	0.0000	5.0	3.6
Deaths over the first 24 hours of life due to preventable causes (2000-2009)	1	19	556	385	1.5	0.0000	8.4	5.8
	2	22	676	555	1.2	0.0002	10.2	8.4
Deaths over the first 24 hours of life due to preventable causes (2010-2019)	1	18	383	229	1.7	0.0000	10.0	6.0
	2	16	319	203	1.6	0.0000	8.3	5.3
	3	6	303	208	1.5	0.0000	7.9	5.4
	4	16	216	161	1.4	0.0120	5.6	4.1

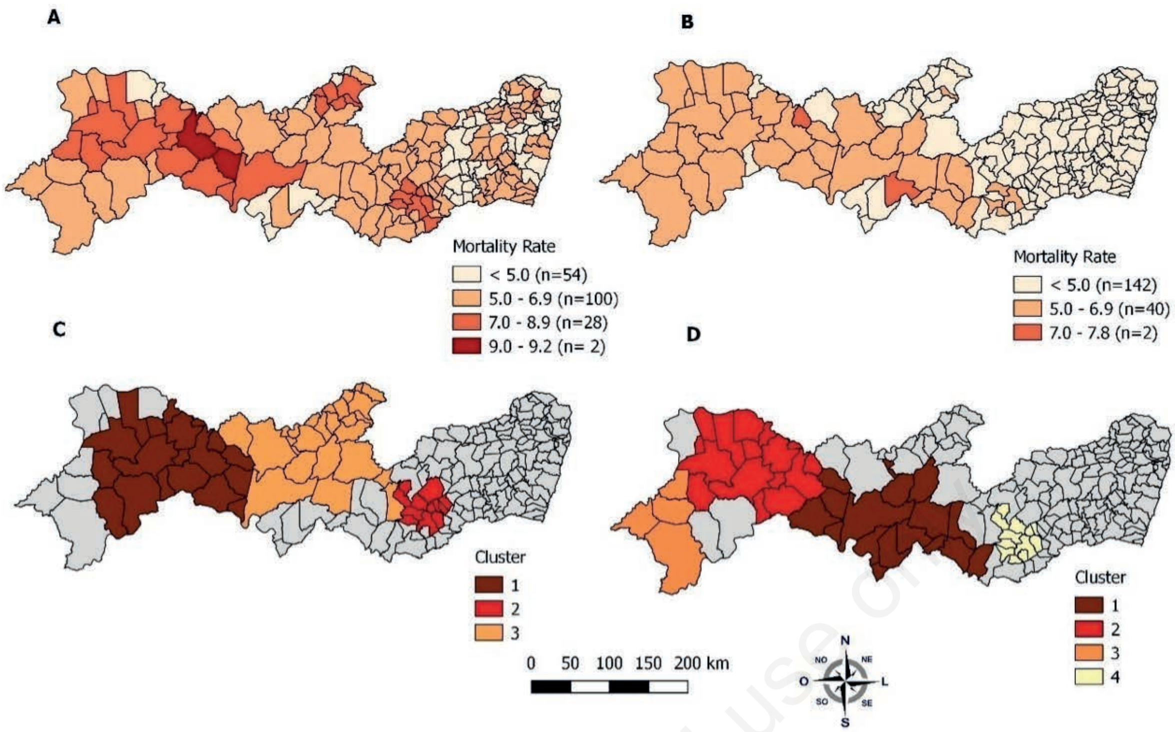

Figure 2. Spatial distribution of the total mortality rate over the first 24 hours of life in Pernambuco, Brazil. Estimated by means of the Bayesian method (per thousand births) during the periods of 2000-2009 (A) and 2010-2019 (B), and clusters for the periods of 2000-2009 (C) and 2010-2019 (D).

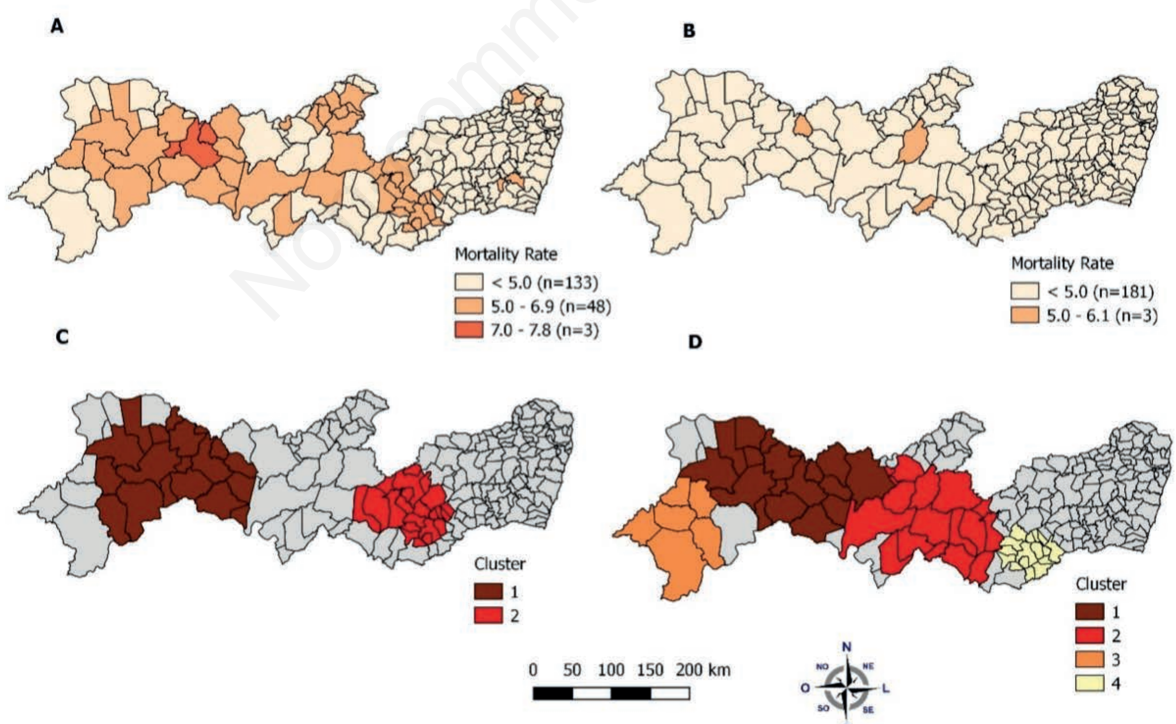

Figure 3. Spatial distribution of the mortality rate over the first 24 hours of life due to preventable causes in Pernambuco, Brazil. Estimated by means of the Bayesian method (per thousand births) during the periods 2000-2009 (A) and 2010-2019 (B) and clusters for the periods 2000-2009 (C) and 2010-2019 (D).

Discussion

The findings presented here indicate presumptive links with biological and healthcare conditions that influence early deaths and it is therefore necessary to consider the social determinants of health that relate to the real situation of pregnant women and their new-borns (Root *et al.*, 2020). Identification of clusters of early and preventable deaths, in macro-regions with municipalities that have cities with poor socioeconomic conditions, demonstrates the association between social determinants and these outcomes. This relationship has been recognised in different studies (Adeyinka *et al*., 2019). In addition, the social dynamics of health problems differ spatially (Yourkavitch *et al*., 2018). A study carried out in different municipalities in the state of Pernambuco, Brazil, showed that variables representing social need are related to foetal mortality (Canuto *et al*., 2021).

A study similar to ours, carried out in eight Brazilian federative units (*i.e*., the states plus the federal district), found that the rates of deaths over in the first 24 hours had decreased in the period from 2010 to 2015, from 2.7 to 2.3 per 1000 live births (Teixeira *et al*., 2019). Our finding in Pernambuco is in line with these results, while the stronger decrease (32.7%) can be explained by the longer period studied and that it also included the end of the second decade. These results are indisputably due to measures implemented in relation to the pregnancy-postpartum cycle that have been fundamental for decreasing early neonatal deaths. These measures included access to effective prenatal care; advances in medical technologies; good delivery and birth care practices, including humanised obstetric care; organisation of the healthcare network for women and new-borns; and availability of intensive care for managing neonatal diseases (Kc *et al*., 2020).

It was observed that the proportions of the municipalities in which the total mortality rates over the first 24 hours of life, and those due to preventable causes, were not the same in the two periods. This indicates that there were persisting failures in the state with regard to the care for pregnant women and new-borns. Access to healthcare services and the capacity of these services to resolve problem during the gestational period and delivery are factors that reduce the risk of premature death, as shown by a study carried out in the state of São Paulo (Guerra *et al*., 2019). A study in China showed that basic maternal healthcare management service during pregnancy impacted neonatal indicators in both urban and rural areas in a positive way (Zhao *et al*., 2020).

The present study identified larger clusters in the second decade studied, which shows that there was an increase in the number of areas with vulnerabilities. These areas require strategic actions in order to reduce premature mortality. In health care planning, at different management levels (state, regional and local), the main gaps in maternal and child health care need to be considered, including deaths that may be prevented through healthcare actions (Mendes *et al*., 2019; Weiland *et al*., 2021). Strengthening and expanding the obstetrics and neonatology care network, prioritizing immediate low-cost actions, such as early prenatal care, would reduce the number of premature deaths (Al-Sheyab *et al*., 2020). Prevention of complications during pregnancy and the anticipation of risk conditions have been shown effective in reaching these goals (Justino *et al*., 2019).

The results show that the risks of mortality due to premature birth and due to preventable causes increased with increasing distance from Macro-region 1 (the metropolitan region of the state capital Recife), *i.e*., these risks were found to be greater in the macro-regions of Sertão, Agreste and Vale do São Francisco and Araripe, areas that lack installed capacity of obstetric care and human resources (Lima *et al*., 2020). In these socioeconomically vulnerable regions, the risk of infant and neonatal death is therefore higher (Grady *et al*., 2017). Public policies dealing with premature deaths need to be articulated by each sector given the scenario of health disparities that exist in these locations (Grady *et al*., 2017). The presence of clusters at the municipality level in a large part of Pernambuco State found in this study reflects health inequalities. There is a need to identify the barriers access to primary healthcare services and the quality provided there (Canuto *et al*., 2021). In economically disadvantaged places, spatial differences regarding early neonatal mortality rates are linked to health inequalities and, consequently, also to uneven distribution of, and differentiated access to, healthcare services (Boutayeb *et al*., 2020).

Additionally, the heterogeneous distribution of clusters of municipalities found for the periods analysed in this study shows that, even though clearly important, one-off actions and programmes barely have any overall effects with regard to decreasing the rates of very early, neonatal mortality (Lima *et al*., 2020). Extension of primary care to more distant areas in Macro-region 1 did not accentuate the decreasing trend in neonatal deaths, unlike what has been observed for post-neonatal components (Lima *et al*., 2020). This once again corroborates the need for integration of public policies in consideration of the causes that determine neonatal death over the first 24 hours of life.

This study had limitations relating to its use of secondary data. This may have underestimated the rates calculated, due to underreporting and incomplete information systems. Another limitation is related to use of municipalities as the unit of analysis, which may have masked spatial inequalities within them.

Conclusions

This study allowed us to identify inequalities regarding the distribution of deaths that occurred over the first 24 hours of life and their preventability. The clusters of municipalities that were identified are priority areas for interventions where an effective maternal and neonatal care network must be ensured. The statistical method of spatial scanning made it possible to estimate risk coefficients for the two events. These may be used in healthcare services supporting the planning and assessment of healthcare policies aimed at reducing infant mortality and its components.

References

Adeyinka DA, Olakunde BO, Muhajarine N, 2019. Evidence of health inequity in childsurvival: spatial and Bayesian network analysis of stillbirth rates in 194 countries. Sci Rep 9:19755, 1-11.

Al-Sheyab NA, Khader YS, Shattnawi KK, Alyahya MS, Batieha A, 2020. Rate, risk factors, and causes of neonatal deaths in Jordan: analysis of data from Jordan Stillbirth and Neonatal Surveillance System (JSANDS). Front Public Health 595379:1-10.

Assunção RM, Barreto SM, Guerra HL, Sakurai E, 1998. Maps of epidemiological rates: a Bayesian approach. Cad Saúde Pública 14:713-23.

Baqui AH, Mitra DK, Begum N, Hurt L, Soremekun S, Edmond K, Kirkwood B, Bhandari N, Teneja S, Mazumder S, Nisar MI, Jehan

F, Ilyas M, Ali M, Ahmed I, Ariff S, Soofi SB, Dhingra U, Dutta A, Ali SM, Ame SM, Semrau K, Hamomba FM, Grogan C, Hamer DH, Bahl R, Yoshida S, Manu A, 2016. Neonatal mortality within 24 hours of birth in six low- and lower-middle-income countries. Bull World Health Organ 94:752-8.

Boutayeb A, Lamlili M, Ouazza A, Abdu M, Azouagh N, 2020. Infant mortality in Sudan: Health equity, territorial disparity and social determinants of health. J Public Health Afr 10:133-6.

Brazilian Ministry of Health, 2021. Departamento de Informática do SUS; Ministério da Saúde. DATASUS [Online]. Available from: https://datasus.saude.gov.br/informacoes-de-saude-tabnet/

Canuto IMB, Macêdo VM, Frias PG, Oliveira CM, Costa HVV, Portugal JL, Bonfim CV, 2021. Spatial patterns of avoidable fetal mortality and social deprivation. Rev Bras Epidemiol 24 [Epub ahead of print]. doi: 10.1590/1980-549720210007.supl.1.

Castro ECM, Leite AJM, Guinsburg R, 2016. Mortality in the first 24h of very low birth weight preterm infants in the Northeast of Brazil. Rev Paul Pediatr 34:106-13.

Desalew A, Gelano TF, Semahegn A, Geda B, Ali T, 2020. Childhood hearing impairment and its associated factors in sub-Saharan Africa in the 21st century: A systematic review and meta-analysis. SAGE OpenMed 8:1-11.

Grady SC, Frake AN, Zhang Q, Bene M, Jordan DR, Vertalka J, DosSantos TC, Kadhim A, Namanya J, Pierre LM, Fan Y, Zhou P, Barry FB, Kutch L, 2017. Neonatal mortality in East Africa and West Africa: a geographic analysis of district-leveldemographic and health survey data. Geospat Health 12:137-50.

Guerra AB, Guerra LM, ProbstLF,Gondinho BVC, Ambrosano GMB, Melo EA, Brizon VSC, Bulgareli JV, Cortellazzi KL, Pereira AC, 2019. Can the primary health care model affect the determinants of neonatal, post-neonatal and maternal mortality? A study from Brazil. BMC Health Serv Res 19:1-11.

Instituto Brasileiro de Geografia e Estatística, 2017. IBGE Cidades [Online]. Available from: https://cidades.ibge.gov.br/brasil/pe/panorama

Justino DCP, Lopes MS, Santos DCP, Andrade FB, 2019. Historicalevaluationof children'spublic health policies in Brazil: integrative review. Rev Ciência Plural 5:71-88.

Kc A, Jha AK, Shrestha MP, Zhou H, Gurung A, Thapa J, Budhathoki SS, 2020. Trends for Neonatal Deaths in Nepal (2001-2016) to Project Progress Towards the SDG Target in 2030, and Risk Factor Analyses to Focus Action. Matern Child Health J 23:5-14.

Kulldorf M. SaTScan User Guide. Software for the spatial, temporal, and space-time scan statistics, 2021 [Online]. Available from: https://www.satscan.org/techdoc.html

Lima SS, Braga MC, Vanderlei LCM, Luna CF, Frias PG, 2020. Assessment of the impact of prenatal, childbirth, and neonatal care on avoidable neonatal deaths in Pernambuco State, Brazil: an adequacy study. Cad Saúde Públ 36:1-12.

Lohela TJ, Nesbitt RC, Pekkanen J, Gabrysch S, 2019. Comparing socioeconomic inequalities between early neonatal mortality and facility delivery: cross-sectional data from 72 low- and middle-income countries. Sci Rep 9:1-11.

Malta DC, Duarte EC, Almeida MF, Dias MAS, Morais Neto OL, Moura L, Ferraz W, Souza MFM, 2007. List of avoidable causes of deaths due to interventions of the Brazilian Health System. Epidemiol Serv Saúde 16:233-44.

Malta DC, Sardinha LMV, Moura L, Lansky S, Leal MC, Szwarcwald CL, França E, Almeida MF, Duarte EC. Update of avoidable causes of deaths due to interventions at the Brazilian Health System. Epidemiol Serv Saúde 19:173-6.

Mendes RB, Santos JMJ, Prado DS, Gurgel RQ, Bezerra FD, Gurgel RQ, 2019. Maternal characteristics and type of prenatal care associated with peregrination before childbirth. Rev Saúde Públ 53:1-10.

Pernambuco State Secretariat of Health, 2016. Perfil socioeconômico, demográfico e epidemiológico: Pernambuco 2016. 1ª Ed. Recife. Pernambuco Secretaria Estadual de Saúde, Secretaria Executiva de Vigilância em Saúde, Diretoria Geral de Promoção, Monitoramento e Avaliação da Vigilância em Saúde, 238 pp. Available from: http://portal.saude.pe.gov.br/secretaria/perfil-socioeconomico-demografico-e-epidemiologico

Pinto LF, Freita MPS, Figueiredo AWS, 2018. National Information and Population Survey Systems: selected contributions from the Ministry of Health and the IBGE for analysis of Brazilian state capitals over the past 30 years. Ciênc Saúde Colet 23:1859-70.

QGIS.org, 2021. QGIS geographic information system. QGIS Association. Available from: http://www.qgis.org

Root ED, Bailey ED, Gorham T, Browning C, Song C, Salsberry P, 2020. Geovisualization and Spatial Analysis of Infant Mortality and Preterm Birth in Ohio, 2008-2015: Opportunities to Enhance Spatial Thinking. Public Health Rep 135:472-82.

Rutstein DD, Berenberg W, Chalmers TC, Child CG, Fishman AP, Perrin EB, Feldman JJ, Leaverton PE, Lane JM, Sencer DJ, Evans CC, 1976. Measuring the Quality of Medical Care- A Clinical Method. N Engl J Med 294:582-8.

SaTScan™, 2016. Software for the spatial, temporal and space-time scan statistics. SaTScan v9.4.4 [Internet]. Available from: https://www.satscan.org/

Teixeira JAM, Araújo WRM, Maranhão AGK, Cortez-Escalante JJ, Rezende LFM, Matijasevich A, 2019. Mortality on the first day of life: trends, causes of death and avoidability in eight Brazilian Federative Units, between 2010 and 2015. Epidemiol Serv Saude 28:1-11.

Tesema GA, Teshale AB, 2021. Residential inequality and spatial patterns of infant mortality in Ethiopia: evidence from Ethiopian Demographic and Health Surveys. Trop Med Health 49:1-15.

Weiland M, Santana P, Costa C, Doetsch J, Pilot E, 2021. Spatial access matters: an analysis of policy change and its effects on avoidable infant mortality in Portugal. Int J Environ Res Public Health 18:1-18.

World Bank Group. World Bank Open Data, 2021 [Online]. Available from: https://data.worldbank.org/ Available from: April 14, 2021.

Yourkavitch J, Burgert-Brucker C, Assaf S, Delgado S, 2018. Using geographical analysis to identify child health inequality in sub-Saharan Africa. PLoS One 13:1-23.

Zhao P, Han X, You L, Zhao Y, Yang L, Liu Y, 2020. Effect of basic public health service project on neonatal health services and neonatal mortality in China: a longitudinal time-series study. BMJ Open 10:1-6.