Revista Brasileira de Enfermagem
REBEn

SUPPLEMENTARY EDITION 4
WOMEN'S AND CHILDREN'S HEALTH

ORIGINAL ARTICLE

Spatial analysis of inequalities in fetal and infant mortality due to avoidable causes

Análise espacial das desigualdades na mortalidade fetal e infantil por causas evitáveis

Análisis espacial de las desigualdades en la mortalidad fetal e infantil debido a causas evitables

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How to cite this article:
Bonfim CV, Silva APSC, Oliveira CM, Vilela MBR, Freire NCF. Spatial analysis of inequalities in fetal and infant mortality due to avoidable causes. Rev Bras Enferm. 2020;73(Suppl 4):e20190088. doi: http://dx.doi.org/10.1590/0034-7167-2019-0088

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Submission: 02-09-2019 **Approval:** 07-01-2019

ABSTRACT

Objectives: to analyze social inequalities in spatial distribution of fetal and infant mortality by avoidable causes and identify the areas of greater risk of occurrence. **Methods:** avoidable deaths of fetal and infant residents of Recife/Brazil were studied. The rates of avoidable fetal and infant mortality were calculated for two five-year periods, 2006-2010 and 2011-2015. The scan statistics was used for spatial analysis and related to the social deprivation index. **Results:** out of the total 2,210 fetal deaths, 80% were preventable. Avoidable fetal mortality rates increased by 8.1% in the five-year periods. Of the 2,846 infant deaths, 74% were avoidable, and the infant mortality rate reduced by 0.13%. **Conclusions:** in the spatial analysis, were identified clusters with higher risk for deaths. The social deprivation index showed sensibility with areas of worse living conditions.
Descriptors: Vital Statistics; Infant Mortality; Fetal Mortality; Spatial Analysis; Social Inequity.

RESUMO

Objetivos: analisar as desigualdades sociais na distribuição espacial da mortalidade fetal e infantil por causas evitáveis e identificar as áreas de maior risco de ocorrência. **Métodos:** foram estudados os óbitos fetais e infantis evitáveis de residentes do Recife/Brasil. As taxas de mortalidade fetal evitável e mortalidade infantil evitável foram calculadas para dois períodos de cinco anos, 2006-2010 e 2011-2015. A estatística *scan* foi utilizada para análise espacial e relacionada ao índice de privação social. **Resultados:** do total de 2.210 óbitos fetais, 80% foram evitáveis, e a taxa de mortalidade fetal aumentou 8,1% nos períodos de cinco anos. Dos 2.846 óbitos infantis, 74% foram considerados evitáveis e a taxa de mortalidade infantil reduziu em 0,13%. **Conclusões:** a análise espacial identificou *clusters* com risco aumentado de morte. O índice de privação social mostrou sensibilidade com as áreas de pior condição de vida.
Descritores: Estatísticas Vitais; Mortalidade Infantil; Mortalidade Fetal; Análise Espacial; Iniquidade Social.

RESUMEN

Objetivos: analizar las desigualdades sociales en la distribución espacial de la mortalidad fetal e infantil por causas prevenibles e identificar las áreas de mayor riesgo de ocurrencia. **Métodos:** se estudiaron las muertes fetales e infantiles prevenibles de residentes de Recife/Brasil. Se calcularon las tasas de mortalidad fetal e infantil prevenibles para dos períodos de cinco años, 2006-2010 y 2011-2015. Para el análisis espacial, utilizamos las estadísticas de escaneo y las relacionamos con el índice de privación social. **Resultados:** de las 2,210 muertes fetales, el 80% era prevenible y la tasa de mortalidad fetal aumentó un 8,1% en los períodos de cinco años. De las 2,846 muertes infantiles, el 74% era prevenible, y la tasa de mortalidad se redujo en 0,13%. **Conclusiones:** en el análisis espacial, se identificaron grupos con mayor riesgo de muerte. El índice de privación social mostró sensibilidad con las áreas con las peores condiciones de vida.
Descriptores: Estadísticas Vitales; Mortalidad Infantil; Mortalidad Fetal; Análisis Espacial; Inequidad Social.

INTRODUCTION

Infant mortality is a high magnitude event of worldwide transcendence related to biological, sociocultural and care determinants[1]. The state of maternal and child health can be evaluated from these events[2]. Fetal death is the loss of life after the 22nd complete week of pregnancy, which culminates in a stillborn fetus. Although this also allows healthcare assessment, studies have indicated the invisibility of this event, which consequently results in less attention given to its prevention[3-5].

In 2015, the overall stillbirth rate was estimated at 18.4 per 1,000 births (ranging from 16.6 to 21.0), and of 8.1 per 1,000 births in Latin America. In Brazil, in that same year, the estimated rate was 8.6 per 1,000 births[3]. The World Health Organization proposed the overall goal of reducing the rate of stillbirths to 12 per 1,000 births in each country by the year 2035 hence, the 2% reduction rate will have to be more than doubled[5].

Approximately 70% of infant deaths occur due to avoidable causes, particularly through healthcare failures for pregnant women, childbirth and newborns[6-7]. Stillbirth is also avoidable in most cases and its prevention is part of a new global strategy towards the healthcare of women, children and adolescents[8-10]. Avoidable or reducible deaths are considered sentinel events, because they comprise unnecessary or potentially preventable occurrences given the availability of sufficient medical technology and proper functioning of healthcare services[11]. Thus, avoidable deaths are an indicator for the quality of healthcare[8].

The Brazilian list of causes of avoidable deaths through interventions within the National Health System (Brazilian SUS) was created and originally published in 2007 and updated in 2010. Its objective was to classify deaths according to their preventability[12]. This classification indicates the predominance of avoidable deaths, especially those caused by inadequate care provided to the mother, either during pregnancy or childbirth, and to the newborn[7,13].

In modern epidemiology, space-time analysis is used to map the events and associated risk factors. In addition, factors related to the operational and implementation challenges of different health programs can be mapped and analyzed for the development of preventive measures[14]. Studies have indicated that the spatial distribution of mortality is not random. There are important variations and inequalities between geographic areas[15-17]. The approximation of healthcare characteristics and spatial organization facilitates the understanding of their distribution among various social groups, which favors the identification of more vulnerable areas and supports managerial planning and decision-making[14,17].

Hence, indicators for social deficits in association with spatial analysis techniques have become a methodological alternative for mapping intraurban differences through measuring the life conditions[17-19]. This allows the identification of risk conditions originating from adverse socioeconomic circumstances within communities, and the correlation of these conditions to spatial units[20-21]. Composite indices are practical tools for investigating inequalities in healthcare and socioeconomic conditions, and allow the concentration of interventions and resources in areas or groups in greater need[19-22].

OBJECTIVES

To analyze social inequalities in the spatial distribution of fetal and infant mortality due to preventable causes and identify the areas at greater risk of occurrence.

METHODS

Ethical aspects

The project was approved by the Research Ethics Committee of the Aggeu Magalhães Research Center, Oswaldo Cruz Foundation and had the consent from the Health Department of Recife.

Study design and location

This was an ecological study, in which the districts (94) were the main units of spatial analysis. The study area was the municipality of Recife, capital of the state of Pernambuco, in Northeastern Brazil. The city has a territorial extent of 218.5 km^2 (totally urban) and a population of 1,617,183 inhabitants[23]. Recife has been the Brazilian state capital with the most unequal income distribution since 1991. According to the Human Development Atlas 2015 of the United Nations Development Program (UNDP), "the evolution of income inequality described through the Gini Index went from 0.67 in 1991, to 0.68 in 2010", which is considerably higher than the Brazilian mean of 0.49. Recife is among the 50 most unequal municipalities in the country, in which poor and unhealthy areas are juxtaposed with "islands" of expansion of a thriving real estate market in a continuous process of expulsion and marginalization of former residents.

Population

The preventability of fetal and infant deaths was analyzed using the Brazilian list of avoidable death causes through interventions within SUS, which classifies deaths as avoidable, unavoidable and ill-defined[12]. Coefficients of avoidable fetal mortality (CFM) per one thousand total births, and avoidable infant mortality (CIM) per one thousand live births, were calculated based on deaths classified as avoidable.

Data source

A social deprivation index (SDI) was constructed through consulting the following data sources: the mortality information system (*Sistema de Informações sobre Mortalidade*, SIM), the live birth information system (*Sistema de Informações sobre Nascidos Vivos*, Sinasc) and the database of the 2010 population census of the *Instituto Brasileiro de Geografia e Estatística* (IBGE).

Study protocol, analysis of results and statistics

To bring greater stability to data relating to small areas that are subject to random variations, the study period was divided into two five-year periods: 2006 to 2010 and 2011 to 2015. CFM was calculated by dividing the sum of avoidable fetal deaths in a five-year period by the sum of live births in the same period. CIM was obtained by dividing the sum of avoidable deaths among children under the age of one year in a five-year period by the sum of live births over the same period.

Descriptive spatial analysis was performed using the distribution of coefficients of avoidable fetal and infant mortality over each five-year period according to the district where the mothers lived. The classes of maps were defined by the quartiles of the first five-year period of each of these indicators and to maintain comparability, strata were maintained for the second five-year period.

Scan statistics were used for exploratory spatial analysis on avoidable fetal and infant deaths according to the five-year period of occurrence. This technique uses circular windows corresponding to a given geographical area. The window size can vary, and the window center can move across the surface of the study area. The windows included a different set of nearest neighbors for each position and size and compared the number of deaths in the region with the estimated number of deaths if the event had occurred homogeneously across the municipality, i.e., following Poisson distribution. Since the window moved over all centroids of the districts, its radius varied continuously from zero to the maximum radius, which in this study did not include more than 20% of total births for CFM and 20% of live births for CIM. The probability function was maximized over all windows to identify which of them represented the most probable clusters[24].

The number of districts, the number and relative risk of observed and estimated deaths, p-value and proportions of deaths, total births and live births were identified for each cluster in relation to the total for the municipality. In the present analysis, all clusters identified were presented regardless of p-values, given the importance of presenting the areas with the greatest concentration of events assessed.

The social deprivation index provides statistical information for the classification of districts according to their socioeconomic conditions[21]. The following variables were used to build the social deprivation index: proportion of permanent private homes without water supply connected to the main network; proportion of permanent private homes with no garbage removal service; proportion of permanent private homes without a bathroom for the exclusive use of people living there; proportion of permanent private homes without sewage collection through the main general network for either sewage or pluvial discharge; proportion of permanent private homes with no nominal monthly income; and proportion of permanent private homes in which the person responsible for the home was illiterate.

The social deprivation index of each district was calculated as the standardized mean of economic and social variables. In each district, was determined the occurrence relative to a socioeconomic variable. The district that presented the greatest occurrence relating to a given variable received a score 1. The district with the lowest occurrence received a score 0. The scores of the remaining districts were calculated according to the formula:

$$\text{Sdistrict,yv} = (\text{OCyv} - \text{OCCMn,v}) / (\text{OCmax,v} - \text{OC min,v})$$

Where *Sdistrict,yv* represented the score of district "y" in relation to variable "v"; *OCyv* represented the occurrence of variable "v" in district "y"; *OCCMn,v* represented the minimum occurrence of variable "v" observed among all districts; and *OCmax,v* represented the maximum occurrence of variable "v" observed among all districts.

Then, the SDI of each district was calculated as the mean of the previously calculated scores:

$$\text{IPSy} = \sum_{v}^{n} \text{Sbairro,v}/n$$

Where SDIy was the social deprivation index of district "y" and n was the number of variables used in the calculation. Districts were grouped into terciles, which allowed stratification of social deficits as the following dimensions: low (stratum I), medium (stratum II) and high (stratum III).

The digital grid of the district was obtained by aggregating the census tracts of the 2010 demographic census. Spatial analyzes were performed using the TerraView software, version 4.2.2, and the SaTScan software, version 9.3.1.

RESULTS

Over the study period, were reported 2,210 fetal deaths in Recife. Out of this total, 1,769 were classified as avoidable (80.0%). During the five-year period 2006-2010, 1,071 deaths were reported, of which 834 were avoidable (77.6%). Between 2011 and 2015, there were 1,139 deaths, of which 935 were avoidable (82.1%). The coefficients of avoidable fetal mortality were 7.4 and 8.0 per 1,000 total births for each respective five-year period, which represented an increase of 8.1%.

The spatial distribution showed that 24.5% of the districts in Recife presented coefficients of avoidable fetal mortality greater than 9.4 per 1,000 total births during the first five-year period (Figure 1A and Table 1). This proportion was 35.1% during the second five-year period (Figure 1B and Table 1).

The exploratory analysis by means of scan statistics indicated four clusters during the first five-year period. These four clusters combined accounted for 17.7% of total births and 25.5% of avoidable fetal deaths in Recife (Figure 1C and Table 1). In a cluster located in the eastern portion of the municipality that included 12 districts, were concentrated 5.7% of births and 8.8% of avoidable fetal deaths, and the risk of death was 60% greater than the expected risk for the area if the distribution of deaths were homogeneous across the area covered by Recife (Table 1). In the second five-year period, seven clusters were detected through the scan statistics, which accumulated 21.3% of the total births and 31.6% of avoidable fetal deaths (Figure 1D and Table 1). Cluster 1, located in the northern portion of Recife, was formed by six districts and accounted for 8.2% of the total births and 11.6% of avoidable fetal deaths, and presented a risk of death that was 50% greater than what would have been expected (Figure 1D and Table 1).

In the SIM, were recorded 2,846 infant deaths, of which 2,107 (74.0%) were considered avoidable. Between 2006 and 2010, there were 1,473 deaths, of which 1,100 (74.7%) were avoidable. Between 2011 and 2015, there were 1,373 deaths, of which 1,007 (73.3%) were avoidable. The coefficients of avoidable infant death were 9.9 and 8.7 per 1,000 live births over each five-year period, thus showing a decrease of 0.13%.

Table 1 - Characteristics of clusters of avoidable fetal and infant deaths, Recife, Pernambuco, Brazil, 2006-2015

Cluster	Districts (N)	Óbitos (N) Observed	Óbitos (N) Expected	RR	Valor de *p*	Deaths (%)	Births (%)
Fetal deaths (2006-2010)							
1	12	70	45	1.6	0.055	8.8	5.7
2	4	43	29	1.5	0.791	5.4	3.7
3	3	47	34	1.4	0.973	5.9	4.3
4	1	43	32	1.4	0.991	5.4	4.0
Fetal deaths (2011-2015)							
1	6	105	74	1.5	0.060	11.6	8.2
2	6	84	59	1.5	0.231	9.3	6.6
3	3	21	12	1.8	0.732	2.3	1.3
4	1	16	8	1.9	0.889	1.8	0.9
5	6	42	30	1.4	0.962	4.7	3.3
6	1	3	1	4.6	0.968	0.3	0.1
7	1	14	8	1.8	0.990	1.6	0.9
Infant deaths (2006-2010)							
1	12	114	76	1.6	0.004	10.4	6.9
2	15	265	214	1.3	0.029	24.1	19.5
3	2	18	11	1.7	0.989	1.6	1.0
Infant deaths (2011-2015)							
1	7	82	58	1.4	0.282	8.2	5.8
2	1	73	51	1.5	0.395	7.3	5.1
3	5	53	35	1.5	0.424	5.3	3.5
4	16	179	146	1.3	0.424	17.8	14.5

Note: RR - relative risk.

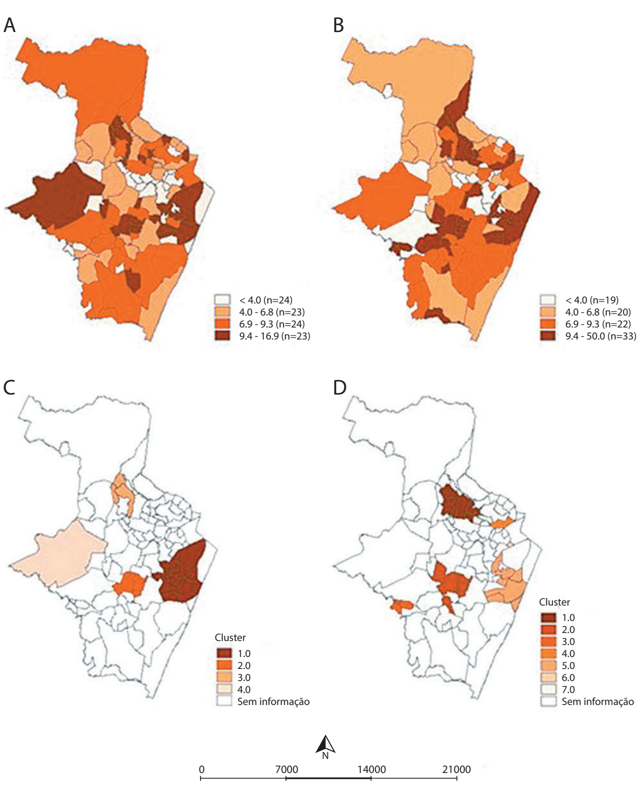

Figure 1 - Spatial distribution of the coefficient of avoidable fetal mortality (per 1,000 total births) over the five-year periods 2006-2010 (A) and 2011-2015 (B), and clusters of the five-year periods 2006-2010 (C) and 2011-2015 (D) in Recife, Pernambuco, Brazil

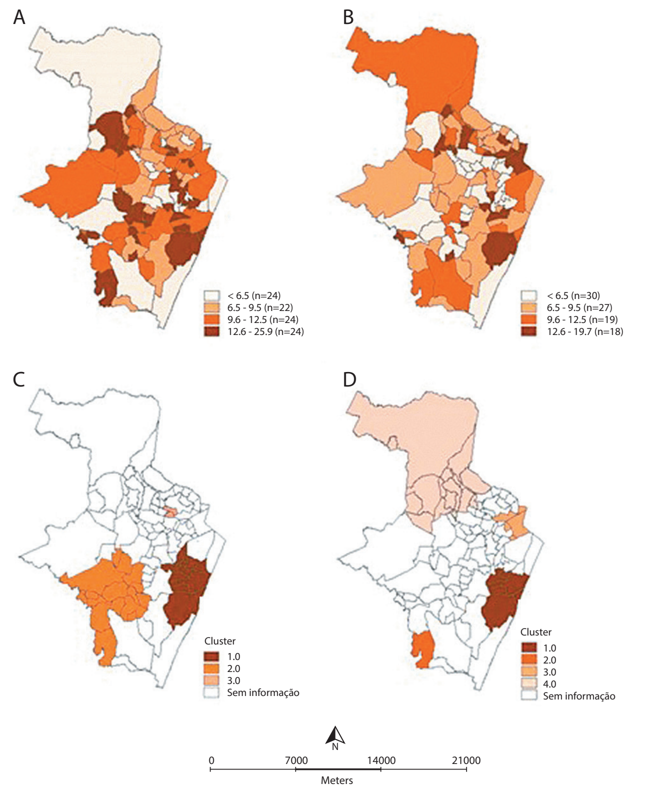

Figure 2 - Spatial distribution of the coefficient of avoidable infant mortality (per 1,000 live births) over the five-year periods 2006-2010 (A) and 2011-2015 (B), and clusters of the five-year periods 2006-2010 (C) and 2011-2015 (D) in Recife, Pernambuco, Brazil

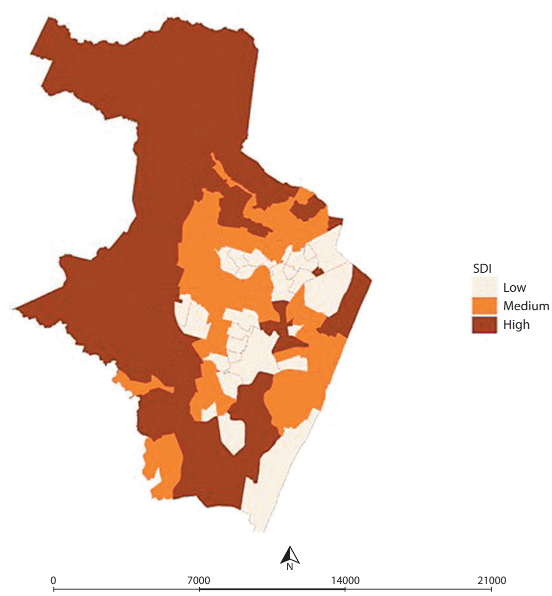

Figure 3 – Spatial distribution of the social deprivation index in the municipality of Recife, Pernambuco, Brazil

According to the spatial distribution, 25.5% of districts in Recife presented coefficients of avoidable infant mortality greater than 12.6 per 1,000 live births over the first five-year period (Figure 2A and Table 1). This proportion was 19.1% over the subsequent five-year period (Figure 2B and Table 1). Three clusters were identified over the first five-year period, accumulating 27.4% of live births and

36.1% of avoidable infant deaths in the municipality (Figure 2C and Table 1). A cluster located in the western portion of the municipality was composed of 15 districts, concentrated 19.5% of live births and 24.1% of the total avoidable infant deaths, and had a risk of death 60% higher than what would have been expected (Table 1).

Four clusters were observed in the second five-year period, and they accumulated 28.9% of live births and 38.6% of avoidable infant deaths (Figure 2D and Table 1). Cluster 4, in northern Recife, was formed by 16 districts, concentrated 14.5% of live births and 17.8% of avoidable infant deaths, and had a risk of death that was 30% greater than what would have been expected (Figure 2D and Table 1).

The social deprivation index presented spatial dependency ($I = 0.18$; $p = 0.014$) on clusters in areas with poorer living conditions, which were predominantly located in northern and western Recife (Figure 3).

DISCUSSION

The results demonstrate a high proportion of avoidable fetal and infant deaths during the period analyzed with different behavior for each coefficient. While an increase in the coefficient of avoidable fetal mortality of almost 10% was observed, the small decrease observed in the coefficient of avoidable infant mortality was nearer to a stability pattern for this period. The presence of clusters in areas of greater social deficit was an important finding. Spatial analysis in conjunction with the social deprivation index provided relevant information on the most vulnerable areas requiring immediate action to reduce infant mortality.

The avoidable fetal mortality rate calculated in this study rose from 7.4 to 8.0 per 1,000 births over the five-year period, which is an increase of 8.1%. In a study, was analyzed the time series of fetal mortality in Brazil in the period from 1996 to 2015, and from 2000, was found a stationary picture for the country and its regions[25]. For the Northeast Region, the fetal mortality rate was around 11 per 1,000 births in 2015[25]. In the 10th Health Region of the state of Ceará, the fetal mortality rate was 14.5 per 1,000 births in the year 2013, and in the state of Ceará, it was 12 per 1,000 births[26]. In the state of Maranhão, the fetal mortality rate was 14.0 per 1,000 births in 2014[27]. In the city of Teresina (PI), the rate was 17.6 per 1,000 births in 2014[28].

The avoidable mortality rate is considered a key indicator of overall health and utilization of health care[29]. Therefore, the reduction of stillbirth depends on a set of strategic interventions that require a clear understanding of the cause and associated factors in order to be effective. Perinatal audit and/or fetal death surveillance is the recommended practice for establishing cause and factors contributing to death[30]. It is also used to identify what worked and what could have been done better in relation to care provided[30]. In Recife, the surveillance of fetal and infant deaths has been carried out since 2006 and contributes to the improvement of information on vital statistics systems and organization of the maternal and child care network[31]. The improvement of the quality of care is directly related to the improvement of vital statistics information for recognizing the situation in each health service[32]. In this sense, strengthening the fetal death surveillance is fundamental for planning the actions aimed at reducing fetal mortality.

Some studies carried out in Brazil reveal that approximately 60% of fetal deaths and 70% of infant deaths occur due to avoidable causes, such as failures in healthcare provided to women during pregnancy and childbirth and to newborns[6-7]. In a study that analyzed infant mortality in the first day of life in the country and in Federation Units, was identified a rate of almost 70% of avoidable deaths. In addition, two thirds of deaths in the first day of life could be avoided by adequate care to women during pregnancy and delivery, to the fetus and the newborn. This fact indicates the primary need for improvements in the quality of maternal and child care[7]. Public health policies can contribute to minimize the health risks of pregnant women and newborns and improve access to health care. The Ministry of Health has made efforts to reduce these indicators by establishing national pacts in 2006 and initiating new programs such as the Stork Network (prenatal and delivery care program) in 2011, which has been established to ensure the right to safe delivery. Additional intersectoral actions could also contribute to health promotion and positive outcomes in maternal and child health[33].

Moreover, issues regarding educational level, family income, access to healthcare services, basic sanitation and living conditions also influence outcomes[17,34]. These determinant factors reflect the greater vulnerability of these mothers to situations of risk and influence fetus and infant survival[17,25,34]. In Nigeria, the results of a study analyzing socioeconomic inequalities in infant mortality among groups defined by wealth, maternal educational level and maternal age clearly showed that a significant proportion of infant deaths could have been avoided if socioeconomic inequalities in rates of infant mortality had been eliminated/reduced by appropriate policies[35]. In Brazil, the investigation of the main socioeconomic determinants of infant mortality showed that socioeconomic variables influenced the determination of infant mortality and were relevant for improving the health status of the Brazilian population. However, income has a more persistent effect on infant deaths compared to educational variables and fecundity in Brazilian municipalities[36].

Scan statistics, which was the exploratory spatial analysis method used in the present study, detected spatial clusters of avoidable fetal and infant mortality in Recife. This methodology presented the novel approach of indicating the proportions of exposure (total births and live births) and deaths for these clusters in relation to the totals found for the municipality. Around 40% of infant deaths reported between 2011 and 2015 occurred among those living in 29 out of the 94 districts of the city, which are mostly regions of greater social deficit. This demonstrates the importance of this finding for the planning and management in the definition of priorities and intervention strategies. In a study that analyzed spatial variations and macroeconomic determinants of infant mortality rate, was reaffirmed the importance of considering geographic factors for the formulation of public health plans and economic development of areas identified as priorities[37].

Moreover, this method allowed quantitative measurement of avoidable deaths in these areas, in relation to a scenario of homogenous distribution over the territory. Thus, the expected value could be compared with observed values, thereby generating a risk estimate. In some areas, the risk was up to 60% greater than what would have been expected, which emphasized the inequalities in occurrences of avoidable fetal and infant mortality. This finding reiterates the need to reduce intraurban differences.

Smaller analysis units, such as census tracts, street blocks or even homes, would allow greater precision for spatial mortality clusters. Admittedly, the use of different spatial units can completely change the apparent spatial patterns and their associations, as well as the geographical clipping in terms of enlargement of the study area, can alter the results of a spatial sweep test[38]. However, the relevance of using districts lies in the availability of this information within healthcare information systems used in Brazil, in addition to the easy comprehension and interpretation of this spatial level. Some of the identified clusters extrapolated the limits of health districts, which are an administrative division commonly used by the healthcare sector.

Socioeconomic status is considered one of the most consistent health determinants of a population, hence the importance of identifying the population segments that still live in poverty. This identification also enables the monitoring of health inequalities, the understanding of their causes and favors the evaluation of the impact of social programs on reducing inequalities[39].

The social deprivation index is one of the most widely used methods for estimating the socioeconomic situation of a given area. Through these indices, the social and material differences by area or region can be described in a statistically efficient and concise manner and used in the analyzes of the health situation[20]. In this study, the social deprivation index was used to identify areas of social deprivation in association with areas of high rates of fetal and infant mortality. Such information may be useful for death surveillance and maternal and child care services.

Like in other regions, the infant mortality rate found in the study showed a reduction between the analyzed periods. Although the coefficient of infant mortality has decreased in many regions, inequalities persist[34,40]. In Egypt, the analysis of socioeconomic inequalities in infant mortality showed an inverse association between infant mortality rates and standard measures of life, and the poor have the highest preterm infant mortality[40].

Social deprivation is associated with a higher risk of adverse perinatal outcomes and social deprivation rates have been adopted by several studies to analyze health and inequalities[19-22]. In maternal and infant health, the social deprivation index was used to test the hypothesis that material deprivation of the community increases the use of health services during the first year of life. A 10% increase in the social deprivation index caused an increase of 1,022 times in the risk of hospitalization and 1,032 times in the length of hospital stay[41]. By applying an indicator of social deprivation, Gonthie et al.[2] showed that social deprivation was significantly associated with a higher risk of prenatal care.

Social deprivation should be taken into account in order to decrease infant mortality inequalities[39,42]. Yun et al.[41] suggested establishing a regional perinatal assistance and medical emergency system in underprivileged regions, along with surveillance and monitoring of pregnant women and newborns in these regions. Improvement of living conditions and effective public policies are contributing factors towards decreasing these inequalities. The inequalities related to infant mortality documented in this study, associated with the identification of geographical areas, can be used to monitor the progress of efforts towards fetal and infant mortality reduction, and provide information for a more efficient allocation of resources through policies and programs for the equitable progress and planning of maternal and child health actions.

Study limitations

The possible methodological limitation of the present study was the use of secondary data originating from healthcare information systems in Brazil, which may have entailed underreporting, despite improvements in the quality and coverage of data in this country. Since the spatial cluster unit used were the districts, there was a possibility of random fluctuations due to small numbers. Data were analyzed by considering temporal clusters of five years as a way of stabilizing and minimizing this effect. The social deprivation index is a useful tool for identifying locations with greater potential for occurrence of the event studied. In this case, these would be priority areas for healthcare interventions, although this does not imply an exact correspondence between underprivileged areas and frequency of deaths.

Contributions to the area of nursing, health or public policy

Regarding both the increase in the coefficient of avoidable fetal mortality and the decrease in the coefficient of avoidable infant mortality observed, clusters either remained in similar regions over both five-year periods or, when broadened, expanded to regions identified as having greater social deficit, as shown by the proposed indicator.

CONCLUSIONS

The spatial analysis method adopted here is another tool used by healthcare surveillance for monitoring fetal and infant mortality, particularly in areas of social inequalities that have repercussions on differences in avoidable deaths. Knowing the exact geographical location of vulnerable regions is an added advantage, because it would help in the effective management of resources. The research strategy used in the present study may contribute to the development of actions with greater equality.

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