Original Article

Spatial distribution and autocorrelation of live births among mothers with advanced maternal age

Distribuição e autocorrelação espacial dos nascidos vivos de mães em idade materna avançada

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ABSTRACT

Objective: to identify the spatial distribution and autocorrelation of live births among mothers with advanced maternal age. **Methods:** ecological study using data from the Live Birth Information System and population estimates. Births were analyzed considering advanced maternal age (≥35 years) in Brazil and its health regions from 2016 to 2023. Rates were calculated by quadrennium, and the spatial distribution was determined through natural breaks. Spatial autocorrelation was assessed using Moran's indices to identify cluster patterns. **Results:** a total of 3,531,207 births from mothers aged 35 years or older were analyzed. The Northern region of Brazil presented the highest rates of births from pregnancies at advanced maternal age. The global Moran's index was significant in all periods, confirming spatial autocorrelation. **Conclusion:** spatial analysis revealed territorial disparities, highlighting the usefulness of Moran's index clusters for understanding the distribution of pregnancies at advanced maternal age. **Contributions to practice:** the findings guide reproductive planning, prenatal care, and the formulation of public policies addressing territorial inequalities related to pregnancies at advanced maternal age.

Descriptors: Reproductive Behavior; Pregnancy; Advanced Maternal Age; Women's Health; Spatial Analysis.

RESUMO

Objetivo: identificar a distribuição e a autocorrelação espacial dos nascidos vivos de mães em idade materna avançada. **Métodos:** estudo ecológico, com dados do Sistema de Informação de Nascidos Vivos e estimativas populacionais. Analisaram-se nascimentos considerando a idade materna avançada (≥35 anos) no Brasil e suas regiões de saúde, no período de 2016 a 2023. As taxas foram calculadas por quadriênio, e a distribuição espacial foi realizada por meio do método de quebras naturais. A autocorrelação espacial foi avaliada com os índices de Moran, identificando padrões de clusters. **Resultados:** analisaram-se 3.531.207 nascimentos de crianças cujas mães possuíam idade igual ou superior a 35 anos. A região Norte do Brasil apresentou as taxas mais elevadas de nascimentos de gestações em idade materna avançada. O índice global de Moran foi significativo em todos os períodos, confirmando a existência de autocorrelação espacial. **Conclusão:** a análise espacial evidenciou disparidades territoriais, reforçando a utilidade dos clusters do Índice de Moran para a compreensão da distribuição da gestação em idade materna avançada. **Contribuições para a prática:** os achados orientam ações de planejamento reprodutivo, pré-natal e a formulação de políticas públicas direcionadas às desigualdades territoriais relacionadas à gestação em idade materna avançada.

Descritores: Comportamento Reprodutivo; Gravidez; Idade Materna Avançada; Saúde da Mulher; Análise Espacial.

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Introduction

Pregnancy at advanced maternal age, defined as that occurring in women aged 35 years or older[1], has shown a growing trend worldwide. In countries within the Organisation for Economic Co-operation and Development, the mean age of women at first childbirth increased from 28.8 years in 2013 (the first year with available data) to 29.8 years in 2023, reflecting a consistent postponement of motherhood in both developed and developing regions. This phenomenon has also been observed in European countries, where 6.1% of births in 2023 occurred among women aged 40 years or older[2].

In Brazil, a similar pattern has been observed. Recent data indicate that, in 2023, 39% of births were from mothers aged 30 years or older, demonstrating a progressive shift in the national reproductive profile. Furthermore, between 2003 and 2023, the proportion of births from mothers aged 35 to 39 years nearly doubled, rising from 7.2% to 13.7%. These findings reveal a significant increase in motherhood within older age groups, a phenomenon influenced by social, educational, and economic factors[3-5].

Overall, pregnancies at advanced maternal age present a higher likelihood of adverse outcomes, requiring adequate organization within health services to ensure qualified preconception and prenatal care[6-7]. However, little is known about how these events are spatially distributed across Brazilian territory and how regional inequalities may influence their occurrence.

In this context, an analysis of the distribution and autocorrelation of pregnancies at advanced maternal age is necessary to support the revision and implementation of public policies that are more appropriate and aligned with the needs of this population, aiming to improve maternal and perinatal outcomes[8].

Given the above, this study aims to identify the spatial distribution and autocorrelation of live births among mothers with advanced maternal age.

Methods

Type and period of the study

This ecological study considered health regions in Brazil (n=430) as the units of analysis, focusing on live births from mothers with advanced maternal age between 2016 and 2023.

The selected period for data sampling was defined based on the Sustainable Development Goals, established at the end of 2015. This timeframe was considered relevant as it marked the first complete year of implementation of the global plan and, primarily, because one of the Sustainable Development Goals concerns reducing maternal mortality by 2030. It is known that pregnancy at advanced maternal age increases the risk of adverse outcomes for both mother and newborn[6,9].

Source and data collection

Data from the Live Birth Information System were used, collected in December 2024. Population projection data were obtained from the Population Estimates Study, available at the Department of Informatics of the Unified Health System.

Study population

The study population comprised live births from mothers with advanced maternal age residing in Brazilian health region.

Data analysis

Maternal age was aggregated into a single sampling group, considering that pregnancy at advanced maternal age occurs among women aged 35 years or older[10]. The decision not to subdivide advanced maternal age into narrower intervals (such as 35–39 and ≥40 years) was based on three methodological

reasons: (a) the need to ensure spatial comparability among all health regions, given that some have a small number of live births in more specific age ranges; (b) limitations in population completeness within certain age strata in some regions, which could compromise rate estimation; and (c) the study's focus, which addresses the spatial distribution of live births from mothers at advanced maternal age rather than risk comparisons among age subgroups. It is noteworthy that stratified analyses may be explored in future studies without prejudice to the central objective of the present investigation.

Crude rates were calculated by dividing the number of live births from mothers aged 35 years or older by the female population in the same age range and health region, multiplied by 1,000. To reduce random variability and enable comparisons across periods, rate calculations were grouped into two four-year spans (quadrennia: 2016–2019 and 2020–2023), in addition to the total period (2016–2023), standardizing the use of the terms "quadrennium" and "period." No rate smoothing techniques were applied, which may increase variability in regions with a smaller female population.

Using the rates for each quadrennium and for the total period, spatial distribution was performed through the natural breaks method. This method groups data into classes that minimize within-group variance while maximizing variance among groups[11]. Its advantages include generating classes that better represent the true data distribution compared to simpler methods such as fixed or predefined intervals.

A first-order queen contiguity matrix was constructed to define neighboring regions for each polygon (mean=5.41). Next, the global Moran's index (I) was applied to measure overall spatial autocorrelation within the dataset, indicating whether observed values follow a significant pattern through pseudo significance tests with 999 permutations across the entire area. The closer the index value to 1.00, whether positive or negative, the greater the spatial autocor-

relation[11]. A significance level of $p < 0.05$ was adopted for all analyses.

However, global autocorrelation may not capture local variations. Therefore, the local Moran's index (Ii), also known as the local indicator of spatial association, was applied to measure spatial autocorrelation locally, allowing the identification of specific hotspot or coldspot clusters or spatial outliers[12]. The indicators are conceptually similar to the global index but are focused on each location and its surroundings, creating the following cluster types: (a) high-high: high values surrounded by high values; (b) low-low: low values surrounded by low values; (c) high-low: high values surrounded by low values; and (d) low-high: low values surrounded by high values. The use of the local index is justified because it provides detailed insights into spatial patterns, complementing the global results.

Maps were generated using a shapefile of Brazilian health regions. Although the National Council of Municipal Health Departments estimates the existence of 438 regions in the country, this study included only 430 due to missing or inconsistent data in eight regions whose recent delimitation was unavailable in the information systems employed[12]. GeoDa® version 1.20.0 and QGIS® version 3.34.0, both widely used for spatial analysis in health research, were employed for the analyses.

Ethical considerations

The research conformed to the guidelines issued by the National Health Council of the Ministry of Health through Resolutions No. 466/12 and 510/2016. Since the data were publicly available, review by the Permanent Committee of Ethics in Research involving Human Beings was not required.

Results

During the period from 2016 to 2023, a total of 3,531,207 live births from mothers aged 35 years or

older were recorded in Brazil. Among these, 1,724,183 occurred in the first quadrennium and 1,807,024 in the second. Figure 1 presents the spatial distribution of pregnancy rates at advanced maternal age for the periods 2016–2019 (A), 2020–2023 (B), and 2016–2023 (C). The maps reveal regional variations, with areas in the Northern region of Brazil showing higher rates.
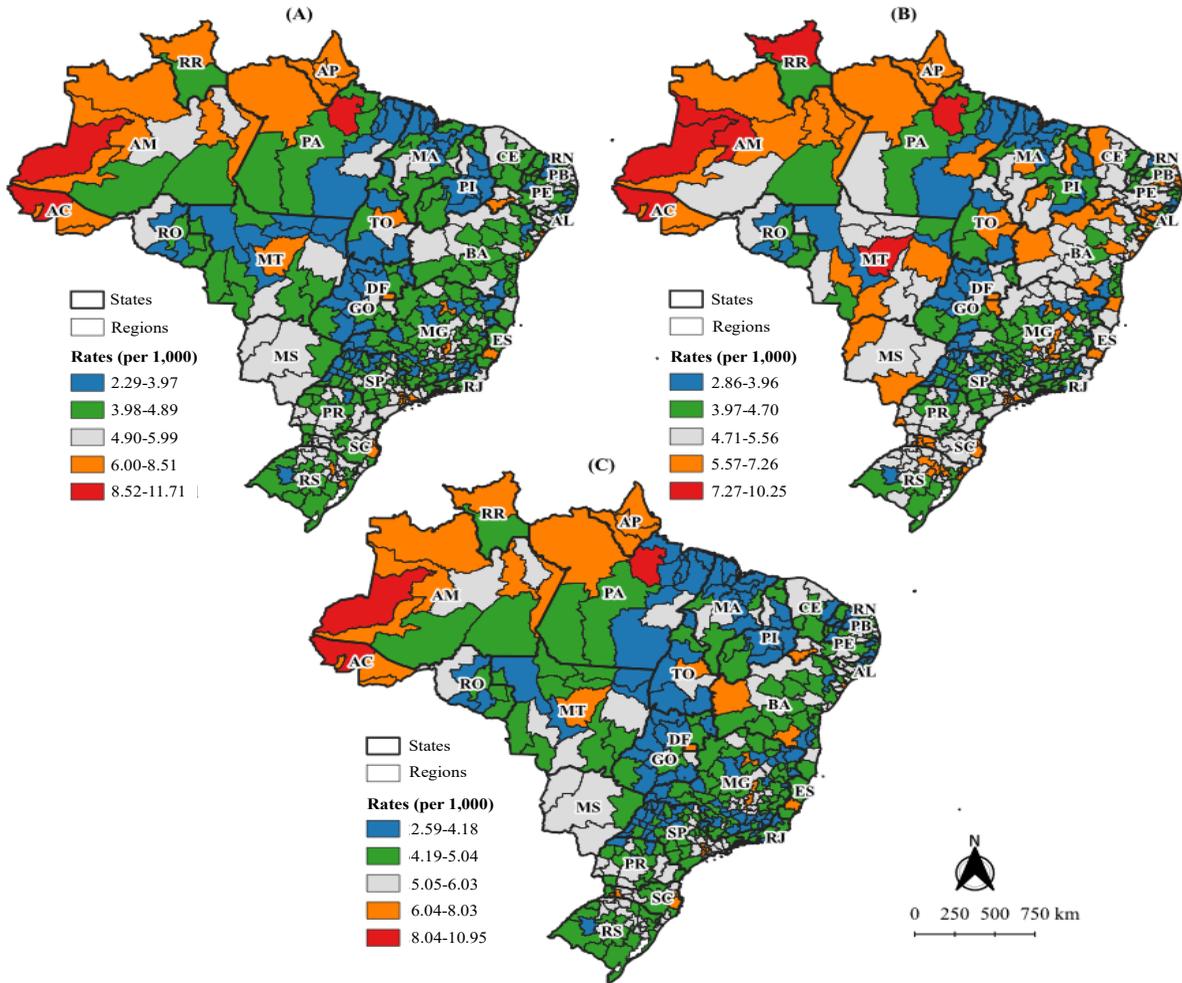

Figure 1 – Spatial distribution of pregnancy rates at advanced maternal age (≥35 years), per 1,000 resident women, across 430 health regions in Brazil, 2016–2019 (A), 2020–2023 (B), and 2016–2023 (C). Maringá, PR, Brazil, 2024

Table 1 presents the clusters derived from the global and local Moran's indices regarding the spatial autocorrelation of pregnancy rates at advanced maternal age in Brazil (2016–2023). High-high and low-low clusters predominated in the analyzed periods, indicating local patterns of high or low incidence. The global Moran's index was significant across all periods, confirming the existence of spatial autocorrelation. There were few occurrences of high-low and low-high patterns.

Table 1 – Characteristics of clusters derived from global and local spatial autocorrelation (Moran's indices) across 430 health regions in Brazil, 2016–2023. Maringá, PR, Brazil, 2024

Period	High-High n (%)	Low-Low n (%)	Low-High n (%)	High-Low n (%)	I (p-value)
2016–2019	34 (7.91)	47 (10.93)	4 (0.93)	13 (3.02)	0.413 (<0.001)
2020–2023	33 (7.67)	54 (12.56)	3 (0.70)	9 (2.09)	0.372 (<0.001)
2016–2023	29 (6.74)	45 (10.47)	5 (1.16)	11 (2.56)	0.393 (<0.001)

I: Global Moran's index

Figure 2 shows the spatial autocorrelation of pregnancy rates at advanced maternal age (≥35 years) in Brazil, by health region, for 2016–2019 (A), 2020–2023 (B), and 2016–2023 (C). High-high clusters prevail in the Northern region, especially in the states of Amazonas, Amapá, and Acre, whereas low-low patterns are concentrated in the Southeast and Central-West regions, particularly in Rio de Janeiro, São Paulo, and Goiás. Spatial outliers (high-low and low-high) were less frequent.
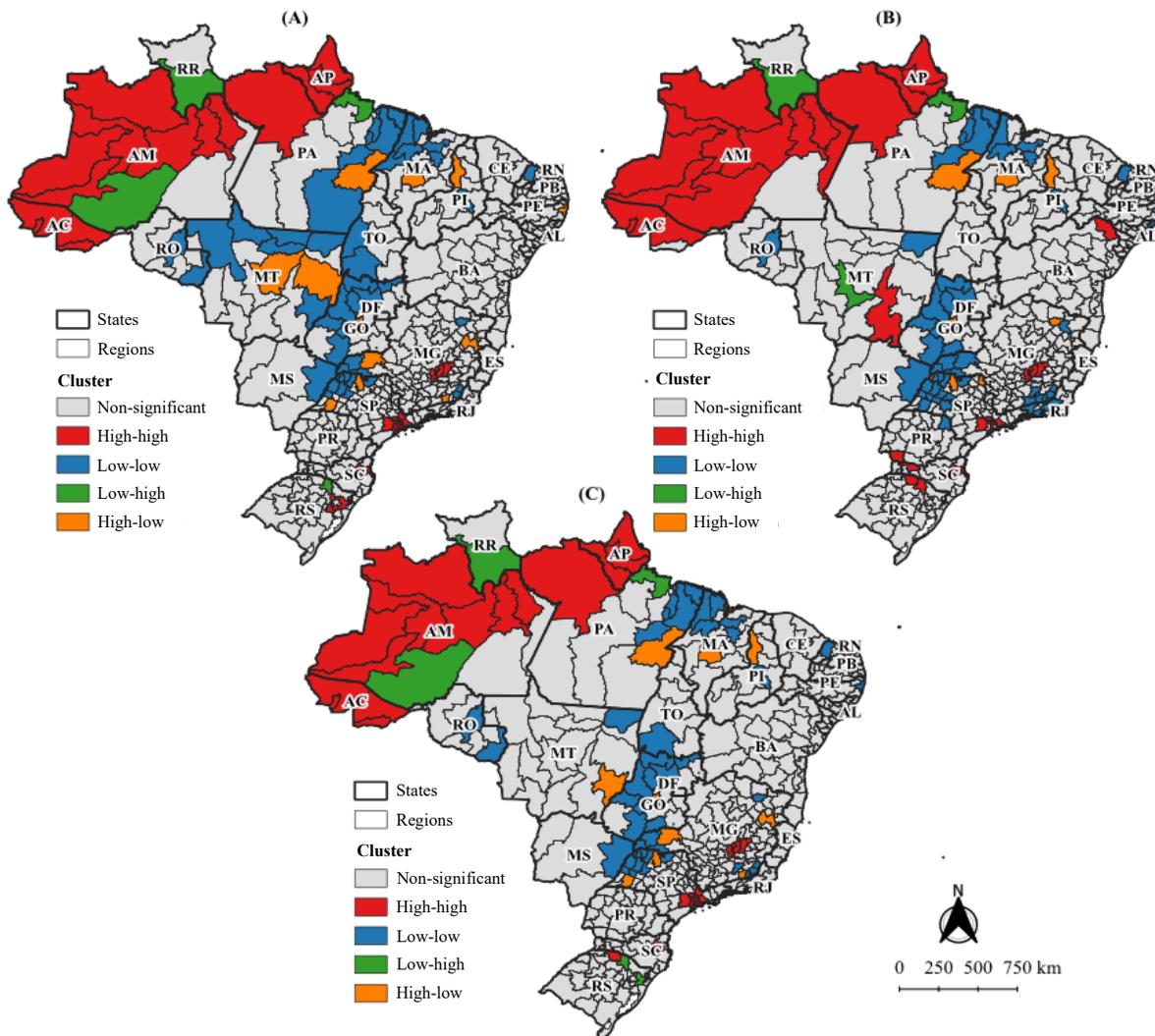

Figure 2 – Spatial autocorrelation of pregnancy rates at advanced maternal age (≥35 years), per 1,000 resident women, across 430 health regions in Brazil, 2016–2019 (A), 2020–2023 (B), and 2016–2023 (C). Maringá, PR, Brazil, 2024

When comparing the quadrennia 2016–2019 (A) and 2020–2023 (B), as shown in Figure 2, the persistence of high-high clusters is observed in the states of Amazonas and Acre, while low-low clusters remain concentrated in the central region. However, there is an expansion of high-high clusters toward the Central-West and Southern regions between periods. Regions with outliers (high-low and low-high) remain isolated, although less frequent in the last time window, suggesting localized changes in spatial patterns.

Discussion

The analysis of the spatial distribution and autocorrelation of live births from mothers with advanced maternal age revealed non-random spatial patterns within Brazilian territory. The Local Indicators of Spatial Association (LISA) and Global Moran maps demonstrated significant spatial autocorrelation in all analyzed periods, with the presence of high-high and low-low clusters, indicating that pregnancies at advanced maternal age are territorially concentrated. A predominance of high-high clusters was observed in the Northern region, extending toward the Northeast, while low-low clusters were mainly concentrated in the Southeast and Central-West regions.

These patterns suggest the influence of specific territorial contexts, in which socioeconomic, demographic, and structural factors shared among neighboring areas contribute to shaping this reproductive profile. The observed spatial autocorrelation reinforces that such configurations reflect common territorial characteristics.

This spatial behavior can be discussed in light of international evidence on the impact of the COVID-19 pandemic on reproductive planning, particularly during periods coinciding with the pandemic context, including discontinuity in contraceptive use, restricted access to sexual and reproductive health services, and increased demand for assisted reproduction techniques among women of older age[13-16]. However, such phenomena must be interpreted considering Brazil's regional inequalities, which decisively influence the identified spatial patterns.

When comparing the two evaluated quadrennia, an expansion of higher-risk clusters was observed in the Northern region, while other areas displayed stability or a slight decrease. This temporal analysis highlights that the spatial dynamics of pregnancies at advanced maternal age accompany demographic transformations and territorial inequalities, reinforcing the dynamic and non-static nature of the observed patterns.

The higher concentration of pregnancies at advanced maternal age within high-high clusters in the Northern region may reflect the interaction of socioeconomic and cultural factors specific to these territories[17-18]. In regions marked by deeper social inequalities, limited access to health services, and geographical barriers, pregnancies at older ages may assume distinct characteristics compared to regions with greater infrastructure and service coverage[19]. Within this context, the identified spatial patterns suggest that territory functions as a modulatory element of reproductive vulnerability[17].

Conversely, the low-low clusters observed in the Southeast and Central-West regions indicate a more homogeneous distribution and lower concentration of pregnancies at advanced maternal age in these territories. These findings may be associated with contexts that offer broader access to information, higher health service coverage, and better socioeconomic conditions, factors that may influence reproductive planning and prenatal care. These patterns underscore the importance of considering regional inequalities when interpreting results and designing public health strategies[20].

Although pregnancy at advanced maternal age is frequently linked to the voluntary decision to postpone motherhood for professional, educational, or personal reasons[21-22], the findings of this study indicate that its occurrence is not uniformly distributed across Brazilian territory. The presence of high-high clusters in specific regions suggests that, beyond individual choices, contextual and territorial factors play a relevant role in shaping these spatial patterns.

Women at advanced maternal age present a higher risk of adverse maternal and perinatal outcomes, such as spontaneous abortion, congenital anomalies, preterm birth, gestational diabetes mellitus, preeclampsia, and a greater frequency of cesarean deliveries[23-25]. In territories where high-high clusters are concentrated, these risks may be amplified by fragilities within healthcare networks, reinforcing the need for adequate organization of prenatal and reproductive planning services[26].

Thus, the identification of consistent spatial patterns of pregnancies at advanced maternal age underscores the significance of territorial analysis for health planning. The identified clusters enable the recognition of priority areas for interventions, contributing to the design of actions aimed at reducing maternal and perinatal risks associated with older maternal age, as well as strengthening equity in maternal healthcare across Brazilian territory[27].

Study limitations

Study limitations include the use of secondary data from the Live Birth Information System, in which data entry may present inconsistencies or under-reporting, potentially affecting the accuracy of the analyzed information. Additionally, the absence of socioeconomic variables within the model prevented further exploration of contextual factors that may influence the spatial distribution of pregnancies at advanced maternal age. Rate smoothing techniques were also not applied, which may increase indicator variability in regions with smaller female populations.

Finally, the ecological study design does not allow causal inference, restricting the interpretation of findings to observed associations among territories. Furthermore, the scarcity of national studies exploring the geographic distribution of live births from mothers at advanced reproductive age imposes challenges for deeper analysis and comparability of results.

Contributions to practice

The findings from this study provide important evidence for public health planning and management. The identification of consistent spatial patterns of pregnancies at advanced maternal age (≥35 years), especially the concentration of high-high clusters in Northern Brazil, highlights the need for region-specific strategies for monitoring these pregnancies, which carry greater obstetric risk.

The persistence and expansion of high-rate areas over time point to an increasing phenomenon that requires attention from primary healthcare services, particularly regarding the provision of reproductive planning, preconception counseling, and enhanced monitoring during prenatal care in these regions.

Moreover, spatial autocorrelation patterns reveal territorial inequalities that must be considered in resource allocation and public health policy formulation. By mapping priority regions, the results support more focused interventions, contributing to the reduction of maternal and child risks associated with advanced maternal age.

Conclusion

Non-random patterns were identified within Brazilian territory, demonstrating significant spatial autocorrelation and the presence of high-high and low-low clusters. These findings indicate that births from mothers with advanced maternal age are not uniformly distributed but are concentrated mainly in the Northern and Northeastern regions, while areas in the Southeast and Central-West display lower proportions and more homogeneous clustering. This uneven distribution reflects socioeconomic, cultural, and healthcare access disparities related to sexual and reproductive health services.

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Authors' contribution

Conception and design or analysis and data interpretation; drafting of the manuscript or critical review for intellectual content; final approval of the version to be published; and responsibility for all aspects of the manuscript, ensuring accuracy and integrity in every

part of it: **Cargnin AVE, Piran CMG, Mori MM, Furtado MD, Shibukawa BMC**. Drafting of the manuscript or critical review for intellectual content; final approval of the version to be published; and responsibility for all aspects of the manuscript, ensuring accuracy and integrity in every part of it**: Lehmkuhl CSF, Rodrigues YVS**.

Data availability

The authors declare that the data used in this study are publicly available within the Live Birth Information System. Processed data and generated maps can be requested from the corresponding author.

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