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Original Article

Temporal trends in asthma mortality in Espírito Santo, Brazil, 2010–2023

Tendências temporais da mortalidade por asma no Espírito Santo, Brasil, 2010–2023
Tendencias temporales de la mortalidad por asma en Espírito Santo, Brasil, 2010–2023

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ABSTRACT

Background and Objectives: Asthma is one of the most prevalent chronic respiratory diseases in the world and remains a significant public health problem due to its morbidity, socioeconomic impact, and risk of mortality in severe cases. This study aimed to analyze the temporal trends and sociodemographic patterns of asthma mortality in the state of Espírito Santo, Brazil, between 2010 and 2023. **Methods:** This is an ecological time-series study using data from the Mortality Information System (SIM/DATASUS) and population estimates from the Brazilian Institute of Geography and Statistics (IBGE). Sociodemographic variables and municipal socioeconomic indicators, such as the Human Development Index (HDI) and the Gini index, were analyzed. Temporal trends were assessed using Prais-Winsten regression to estimate the annual change in the number of asthma-related deaths. **Results:** A total of 829 asthma-related deaths were recorded during the study period (mean age: 63.9 years; 64.5% women). Most deaths occurred in a hospital setting (59.6%). Unspecified asthma (ICD-10 J45.9) accounted for 98.6% of cases. A significant increasing trend in the annual number of asthma deaths was observed, with an average absolute increase of 2.19 deaths per year (p = 0.001). **Conclusion:** Mortality from asthma showed an increasing trend in Espírito Santo, highlighting the need to strengthen preventive strategies, improve clinical management, and expand surveillance of respiratory diseases. The results also suggest the importance of public policies aimed at reducing inequalities and improving health information systems to minimize preventable deaths.

Keywords: *Asthma. Mortality. Epidemiology. Health Information Systems.*

RESUMO

Justificativa e Objetivos: A asma é uma das doenças respiratórias crônicas mais prevalentes no mundo e permanece como importante problema de saúde pública devido à sua morbidade, impacto socioeconômico e risco de mortalidade em casos graves. Este estudo teve como objetivo analisar as tendências temporais e os padrões sociodemográficos da mortalidade por asma no estado do Espírito Santo, Brasil, entre 2010 e 2023. **Métodos:** Trata-se de um estudo ecológico de séries temporais com dados do Sistema de Informações sobre Mortalidade (SIM/DATASUS) e estimativas populacionais do Instituto Brasileiro de Geografia e Estatística (IBGE). Foram analisadas variáveis sociodemográficas e indicadores socioeconômicos municipais, como Índice de Desenvolvimento Humano (IDH) e índice de Gini. As tendências temporais foram avaliadas utilizando a regressão de Prais-Winsten para estimar a variação anual no número de mortes relacionadas à asma. **Resultados:** Foram registrados 829 óbitos por asma no período estudado (idade média: 63,9 anos; 64,5% mulheres). A maioria dos óbitos ocorreu em ambiente hospitalar (59,6%). A asma não especificada (CID-10 J45.9) representou 98,6% dos casos. Observou-se tendência crescente significativa no número anual de óbitos por asma, com aumento absoluto médio de 2,19 óbitos por ano (p = 0,001). **Conclusão:** A mortalidade por asma apresentou tendência crescente no Espírito Santo, evidenciando a necessidade de fortalecimento das estratégias preventivas, aprimoramento do manejo clínico e ampliação da vigilância das doenças respiratórias. Os resultados também sugerem a importância de políticas públicas voltadas à redução de desigualdades e à qualificação dos sistemas de informação em saúde para minimizar óbitos evitáveis.

Descritores: *Asma. Mortalidade. Epidemiologia. Sistemas de Informação em Saúde.*

RESUMEN

Justificación y Objetivos: El asma es una de las enfermedades respiratorias crónicas más prevalentes en el mundo y sigue siendo un problema de salud pública significativo debido a su morbilidad, impacto socioeconómico y riesgo de mortalidad en casos graves. Este estudio tuvo como objetivo analizar las tendencias temporales y los patrones sociodemográficos de la mortalidad por asma en el estado de Espírito Santo, Brasil, entre 2010 y 2023. **Métodos:** Este es un estudio ecológico de series temporales que utiliza datos del Sistema de Información de Mortalidad (SIM/DATASUS) y estimaciones de población del Instituto Brasileño de Geografía y Estadística (IBGE). Se analizaron variables sociodemográficas e indicadores socioeconómicos municipales, como el Índice de Desarrollo Humano (IDH) y el índice de Gini. Se evaluaron las tendencias temporales mediante la regresión de Prais-Winsten para estimar el cambio anual en el número de muertes relacionadas con el asma. **Resultados:** Se registraron 829 muertes relacionadas con el asma durante el período de estudio (edad media: 63,9 años; 64,5% mujeres). La mayoría de las muertes ocurrieron en un entorno hospitalario (59,6%). El asma no especificada (CIE-10 J45.9) representó el 98,6 % de los casos. Se observó una tendencia creciente significativa en el número anual de muertes por asma, con un aumento absoluto medio de 2,19 muertes por año (p = 0,001). **Conclusión:** La mortalidad por asma mostró una tendencia creciente en Espírito Santo, lo que subraya la necesid4ad de fortalecer las estrategias preventivas, mejorar el manejo clínico y ampliar la vigilancia de las enfermedades respiratorias. Los resultados también sugieren la importancia de las políticas públicas dirigidas a reducir las desigualdades y mejorar los sistemas de información sanitaria para minimizar las muertes prevenibles.

Palabras Clave: *Asma. Mortalidad. Epidemiología. Sistemas de Información en Salud.*

INTRODUCTION

Asthma is one of the most prevalent chronic respiratory diseases worldwide and represents a major public health challenge due to its high morbidity, socioeconomic burden, and, in severe cases, risk of death.[1-2]

According to the World Health Organization (WHO), more than 260 million people were living with asthma in 2019, and the disease continues to be responsible for thousands of preventable deaths each year. Although effective therapeutic options are available and appropriate clinical follow-up can control symptoms and prevent complications, asthma continues to lead to frequent hospitalizations and premature mortality, particularly in low- and middle-income countries where barriers to diagnosis and treatment persist.[3]

In Latin America, asthma is strongly influenced by social and environmental disparities. Rapid urbanization, exposure to air pollution, inadequate housing conditions, and challenges related to treatment adherence contribute to increased disease severity and poorer clinical outcomes.[4] In Brazil, asthma remains a leading cause of hospital admissions for respiratory diseases within the Unified Health System (SUS). According to national analyses based on DATASUS data, asthma accounted for approximately 1.7 million hospitalizations over the last decades, with an average of around 55,000 admissions per year in recent years. In addition, asthma-related mortality persists, with several hundred deaths reported annually, despite being largely preventable through appropriate management strategies.[5]

Despite advances in public policies, including the expansion of access to essential medications and improvements in primary health care, Brazil continues to exhibit significant regional disparities in asthma morbidity and mortality. These heterogeneities are shaped by socioeconomic conditions, environmental exposures, health service organization, and unequal access to specialized care, all of which directly influence diagnosis, follow-up, and the prevention of severe outcomes.[6-7] Therefore, regional analyses are essential to accurately characterize the epidemiological profile of asthma and to support more effective and equitable intervention strategies.

Espírito Santo presents important environmental and sociodemographic characteristics that may influence respiratory health outcomes, including intense industrial and port activities in the Greater Vitória Metropolitan Region, rapid urbanization, socioeconomic inequalities, and population aging.[4,8] Previous epidemiological studies conducted in Vitória and the Greater Vitória Metropolitan Region have demonstrated associations between air pollution and increased respiratory morbidity, including asthma and respiratory disease-related hospital admissions among children and adults.[9-11] In Vitória, increases in particulate matter (PM10), sulfur dioxide (SO_2), and ozone (O_3) concentrations were associated with higher risks of respiratory hospitalizations, particularly among vulnerable populations.[9] Additionally, studies conducted in the region have shown that exposure to atmospheric pollutants is associated with increased emergency department visits and respiratory complications, even when pollutant levels remain within national standards.[10-11] Despite these findings, epidemiological investigations specifically addressing trends in asthma mortality in Espírito Santo remain scarce. Therefore, understanding the evolution of asthma mortality in the state is essential to support regional public health planning, environmental surveillance, and preventive strategies.

Monitoring asthma mortality is a key component of disease surveillance and is critical for identifying temporal trends, supporting health policy planning, and guiding resource allocation. Accordingly, this study aimed to analyze temporal trends and sociodemographic patterns in asthma-related mortality in Espírito Santo, Brazil, from 2010 to 2023.

METHODS

Study design and data sources

We conducted an ecological time-series study to analyze asthma mortality in the state of Espírito Santo, Brazil, from January 2010 to December 2023. Mortality data were obtained from the Mortality Information System (SIM), available through the Department of Informatics of the Unified Health System (DATASUS). Population estimates were retrieved from the 2010 and 2022 demographic censuses, as well as from intercensal population projections released by the Brazilian Institute of Geography and Statistics (IBGE).[8]

Data were extracted from the SIM/DATASUS database through the TABNET platform available on the official DATASUS website. Data extraction was independently performed by the authors between January and February 2025 using standardized filters for place of residence (Espírito Santo), year of death (2010–2023), and International Classification of Diseases, 10th Revision (ICD-10) underlying cause-of-death codes. The variables obtained included year of death, sex, age, race/skin color, marital status, municipality of residence, and place of death. Following data extraction, the database was organized and stored in Microsoft Excel spreadsheets and subsequently analyzed using R software.

Inclusion criteria, study population, and variables

The study population consisted of all deaths among residents of Espírito Santo in which asthma was

recorded as the underlying cause of death between January 2010 and December 2023.

We included all records in which asthma was classified as the underlying cause of death according to the 10th Revision of the International Classification of Diseases (ICD-10), considering the following codes: J45 (asthma), J45.0 (predominantly allergic asthma), J45.1 (non-allergic asthma), J45.8 (mixed asthma), and J45.9 (unspecified asthma). Cases classified as status asthmaticus (ICD-10 J46) were not included because the study definition was restricted to deaths explicitly registered under asthma (J45 category) as the underlying cause of death.[12]

Records with missing or inconsistent information regarding cause of death, year of occurrence, or place of residence were excluded from the analysis.

Sociodemographic variables included age, sex, and region of residence. In addition, municipal-level social inequality indicators were analyzed, including the Human Development Index (HDI), ranging from 0 (lower development) to 1 (higher development), and the Gini Index, ranging from 0 (perfect income equality) to 1 (maximum inequality).[13-14]

Annual asthma mortality rates were calculated by dividing the number of deaths in each year by the estimated resident population and multiplying the result per 100,000 population.

Data Analysis

Temporal trends in the annual number of asthma deaths were assessed using Prais–Winsten linear regression, which accounts for first-order serial autocorrelation. Calendar year was included as the independent variable, and the annual number of asthma deaths was used as the dependent variable. The regression coefficient (β) represented the average absolute annual change in the number of deaths. Trends were classified as increasing when the coefficient was positive and $p < 0.05$, decreasing when the coefficient was negative and $p < 0.05$, and stable when $p \geq 0.05$. All statistical analyses were performed using R software, version 4.3.1, in the RStudio environment.[15]

This study used publicly available secondary data without personal identifiers. Therefore, ethical approval was not required, since studies based on anonymized public databases are exempt from evaluation by Research Ethics Committees in Brazil. [16]

RESULTS

A total of 829 deaths attributable to asthma were recorded in Espírito Santo between 2010 and 2023. The mean age at death was 63.9 years (standard deviation (SD) = 23.7). Women accounted for 64.5% of all deaths, indicating a higher mortality burden than that observed among men (35.5%). Regarding race/skin color, 41.6% of deaths occurred among White individuals, followed by Brown (36.7%) and Black (10.5%) individuals (Table 1).

With respect to marital status, deaths were most frequently recorded among widowed individuals (24.8%), followed by those who were married (23.6%) and single (22.3%). Most deaths occurred in hospitals (59.6%), while 29.4% occurred at home and 7.6% in other health facilities.

The municipalities with the highest proportions of asthma deaths were Vila Velha (13.6%), Cariacica (12.7%), Vitória (12.4%), Serra (8.6%), and Cachoeiro de Itapemirim (4.6%). Socioeconomic indicators for the municipalities in which deaths occurred showed a mean Gini Index of 0.527 (SD = 0.05), a mean HDI of 0.738 (SD = 0.06), and a mean per capita income of BRL 911.82 (SD = 465.78) (Table 1).

Table 1. Sociodemographic characteristics of individuals who died from asthma in Espírito Santo, Brazil, 2010–2023.

Variables	Total
Age, years (mean, SD)	63.9 (23.7)
Sex	
Female (n, %)	535 (64.5%)
Male (n, %)	294 (35.5%)
Race/skin color	
White (n, %)	345 (41.6%)
Brown (n, %)	304 (36.7%)
Black (n, %)	87 (10.5%)
Indigenous (n, %)	3 (0.4%)
Yellow (n, %)	2 (0.2%)
Not reported (n, %)	88 (10.6%)
Marital status	
Widowed (n, %)	206 (24.8%)
Married (n, %)	196 (23.6%)
Single (n, %)	185 (22.3%)
Legally separated (n, %)	49 (5.9%)
Common-law marriage (n, %)	7 (0.8%)
Not reported (n, %)	186 (22.6%)
Place of death	
Hospital (n, %)	494 (59.6%)
Home (n, %)	244 (29.4%)
Other health facility (n, %)	63 (7.6%)
Other locations (n, %)	16 (1.9%)
Public road (n, %)	12 (1.5%)
Municipalities with highest mortality counts	
Vila Velha (n, %)	113 (13.6%)
Cariacica (n, %)	105 (12.7%)
Vitória (n, %)	103 (12.4%)
Serra (n, %)	71 (8.6%)
Cachoeiro de Itapemirim (n, %)	38 (4.6%)
Gini Index, mean (SD)	0.527 (0.05)
HDI, mean (SD)	0.738 (0.06)
Per capita household income, BRL (mean, SD)	911.82 (465.78)

Abbreviation: SD: Standard deviation; HDI: Human Development Index.

Building on these population characteristics, the analysis of underlying causes of death demonstrated that unspecified asthma (ICD-10 J45.9) was recorded in 98.5% of cases, indicating limited specification of asthma subtypes in mortality reporting. Predominantly allergic asthma (J45.0) represented 0.7% of deaths, while mixed asthma (J45.8) and non-allergic asthma

(J45.1) accounted for 0.6% and 0.2%, respectively (Table 2).

Table 2. Underlying causes of death due to asthma in Espírito Santo, Brazil, 2010–2023.

ICD-10 code and description	Total
J45.9 – Unspecified asthma (n, %)	817 (98.5%)
J45.0 – Predominantly allergic asthma (n, %)	6 (0.7%)
J45.8 – Mixed asthma (n, %)	5 (0.6%)
J45.1 – Non-allergic asthma (n, %)	1 (0.2%)

Abbreviation: ICD-10: International Classification of Diseases, 10th Revision.

Following the distribution of asthma subtypes, temporal analyses showed fluctuations in mortality throughout the study period. In 2010, 50 deaths were recorded. Mortality declined to its lowest value in 2013 (39 deaths), followed by a progressive increase, peaking at 74 deaths in 2019. Elevated mortality persisted between 2020 and 2022 (range: 69–74 deaths), with a slight decline to 72 deaths in 2023. The mean asthma mortality rate for during the study period was 1.53 deaths per 100,000 population (SD = 0.27), ranging from 1.02 (2013) to 1.93 (2022) (Table 3).

Table 3. Annual number of asthma deaths and crude mortality rates in Espírito Santo, Brazil, 2010–2023.

Year	Deaths	Population (ES)	Mortality rate (per 100,000)
2010	50	3,514,952	1.42
2011	56	3,547,055	1.58
2012	50	3,578,067	1.40
2013	39	3,839,366	1.02
2014	55	3,885,049	1.42
2015	54	3,929,911	1.37
2016	51	3,973,697	1.28
2017	56	4,016,356	1.39
2018	55	3,972,388	1.38
2019	74	4,018,650	1.84
2020	69	4,064,052	1.70
2021	74	4,108,508	1.80
2022	74	3,833,712	1.93
2023	72	3,833,712	1.88
Mean (SD)	-------	------	1.53 (0.27)

Note: Prais–Winsten regression of the annual number of asthma deaths indicated an increasing temporal trend (β = 2.19 deaths per year; 95% CI: 1.14–3.24; p = 0.001). Abbreviation: ES: Espírito Santo. SD: standard deviation.

Prais–Winsten regression indicated a significant increasing trend in the annual number of asthma deaths, with an average absolute increase of 2.19 deaths per year (β = 2.19; 95% CI: 1.14–3.24; p = 0.001). The model explained approximately 60% of the temporal variability in the annual number of deaths (R^2 = 0.60) (Figure 1).

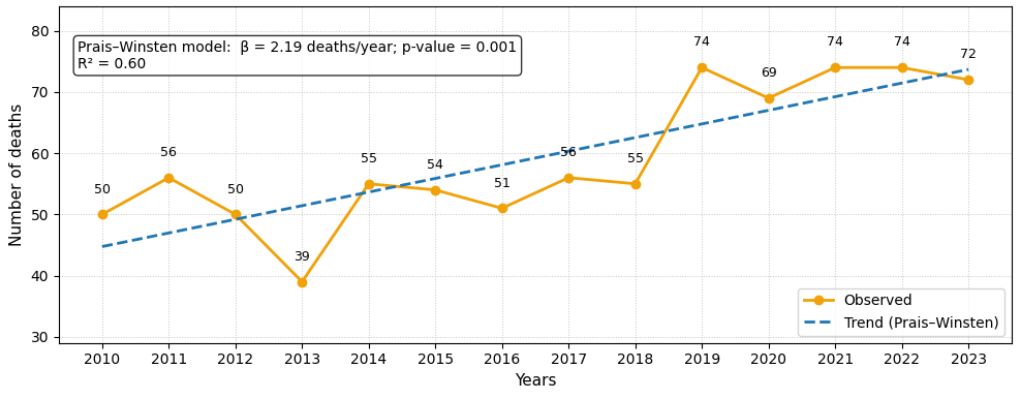

Figure 1. Annual number of asthma deaths and temporal trend estimated by Prais–Winsten regression in Espírito Santo, Brazil, 2010–2023.

Note: The orange line represents the observed annual number of deaths, and the blue dashed line represents the temporal trend estimated by Prais–Winsten regression (β = 2.19 deaths per year; 95% CI: 1.14–3.24; p = 0.001; R^2 = 0.60).

DISCUSSION

This study identified that deaths from asthma in Espírito Santo between 2010 and 2023 were predominantly classified as unspecified asthma (ICD J45.9), with a higher mortality burden among adults and the elderly (mean age of 63.9 years), women, and self-declared white individuals. A progressive increase in the number of deaths was observed over the study period, with a marked increase from 2019 onward.

The predominance of asthma deaths among women

follows the trend described in national and international studies, which point to a greater vulnerability of females to mortality from the disease.[17-18] This difference may be related to biological and hormonal factors that influence inflammatory responses and bronchial reactivity, as well as to behavioral and social aspects. Although women generally seek health services more frequently, which favors diagnosis and follow-up, studies suggest that they are also more exposed to triggering factors, such as the use of hormonal medications and allergic conditions, which may contribute to worse clinical outcomes.[17-18]

The high mean age reinforces that asthma also poses a significant risk in the elderly population, where chronic comorbidities and greater clinical fragility coexist, increasing the likelihood of negative outcomes.[19]

The higher frequency of deaths among White individuals may reflect the demographic composition of the state, but it also highlights the need for more in-depth analysis of the interaction between social determinants, race/skin color, and health outcomes.[20]

Environmental exposures may have contributed to the observed mortality patterns, particularly in municipalities located in the Greater Vitória Metropolitan Region, where industrial and port activities are heavily concentrated. Quantitative evidence from local epidemiological studies supports this concern. Freitas et al.[9], in a time-series analysis of hospital admissions in Vitória between 2001 and 2006, found that each 10 μg/m³ increment in PM10 was associated with a cumulative increase of 9.67% (95%CI: 7.54–11.84) in hospitalizations due to total respiratory diseases and 6.60% (95%CI: 3.75–9.53) among children under five years of age. SO_2 showed a similar pattern, with a cumulative relative risk increase of 6.98% (95%CI: 4.17–9.88) for total respiratory admissions.

In a spatial analysis of outpatient asthma care in Vitória, Castro et al.[10] documented that the three districts with the highest proportional asthma rates in children under six accounted for more than 50% of all respiratory visits and were precisely those with the most precarious socioeconomic and environmental conditions, including proximity to old bus depots, unpaved roads, and industrial complexes, suggesting the combined role of local pollution sources and social vulnerability. Matos et al.[11] analyzing emergency department visits for respiratory diseases in children aged 0–6 in the Metropolitan Region between 2005 and 2010, found that each 10 μg/m³ increment in PM10 raised emergency department visit risk by 2.43% to 3.29% across cumulative exposure windows of 5–7 days; SO_2 showed a cumulative increase of up to 8.80% (95%CI: 2.55–15.44) at three days of exposure. Notably, neighborhood-level disaggregated analyses revealed substantially higher effect magnitudes, reaching 12.27% for PM10 in Jardim Camburi and 9.05% in Vila Velha-Centro, demonstrating that metropolitan-level averages underestimate the local respiratory burden. Pollutants derived from industrial emissions, port operations, mining activities, and heavy vehicle traffic may worsen respiratory symptoms and compromise asthma control, particularly among older adults and individuals with limited access to healthcare. It is important to note that the available epidemiological evidence on air pollution and respiratory morbidity in Espírito Santo is concentrated in the Greater Vitória Metropolitan Region, where the state's air quality monitoring network (RAMQAr) is located. Other regions of the state are not covered by continuous environmental monitoring and likely present distinct exposure profiles such as biomass burning, agricultural dust, and diffuse vehicle emissions, whose health impacts remain understudied. The fact that Cachoeiro de Itapemirim, located outside the metropolitan industrial axis, accounted for 4.6% of asthma deaths suggests that mortality is not restricted to highly industrialized areas and may reflect different environmental and healthcare access determinants across the state.

Socioeconomic conditions may also play an important role in the observed mortality patterns. Municipalities with asthma-related deaths showed moderate HDI values and considerable income inequality, as reflected by the average HDI of 0.738 and Gini Index of 0.527. Social vulnerability may limit access to healthcare services, continuous pharmacological treatment, specialized follow-up, and adequate disease control, thereby contributing to unfavorable outcomes. National evidence reinforces the impact of racial and socioeconomic inequalities on health outcomes in Brazil. Oliveira et al.[7] highlighted persistent disparities in healthcare access and quality of life among socially vulnerable populations, particularly Black individuals. Similarly, Polidoro et al.[21] demonstrated marked spatial inequalities in health indicators between White and Black populations in Porto Alegre, with relative risks for some health conditions exceeding 8.0 in socially vulnerable districts. Previous Brazilian studies have also shown that regions characterized by greater social inequalities tend to present worse respiratory health indicators and greater barriers to preventive care.[10] These findings reinforce the role of socioeconomic and racial inequalities as important social determinants associated with asthma outcomes and highlight the importance of strengthening public health policies aimed at reducing inequities in asthma management and improving access to comprehensive respiratory healthcare.

The high proportion of death records classified as unspecified asthma (98.5%) indicates important limitations in the quality and specificity of death certification, a situation previously described in analyses of secondary health databases in Brazil and

other countries.[5-22] In the ICD-10 classification system, asthma-related deaths may be categorized according to clinical phenotype, including allergic, non-allergic, mixed, or unspecified asthma. However, in routine clinical practice, death certificates are frequently completed without detailed characterization of the asthma subtype, especially in emergency settings or among older adults with multiple comorbidities. This limitation may reflect difficulties in diagnostic confirmation, limited access to complementary clinical information, and inconsistencies in death certificate completion. Consequently, the predominance of unspecified asthma compromises the epidemiological accuracy of mortality statistics and may hinder the planning, monitoring, and evaluation of public health interventions directed toward asthma control. It may also introduce classification bias by limiting the specificity of mortality estimates, reduce comparability with international studies that provide greater detail on asthma phenotypes. Furthermore, it may constrain epidemiological surveillance and the development of interventions targeted to different clinical profiles.

Between 2010 and 2023, asthma mortality varied significantly. The lowest number was recorded in 2013 (39 cases), while the highest values occurred in 2019, 2021, and 2022, with 74 cases each. During this period, there was a significant mean increase of 2.19 deaths per year. Similar patterns have been reported in other Brazilian regions. In Southern Brazil, Paladini et al.[23] identified 1,885 asthma-related deaths between 2013 and 2022, with a significant increasing trend and an annual percentage change of 5.69%, predominantly affecting women and older adults. Likewise, Borges et al.[24] demonstrated that asthma mortality remained heterogeneous across Brazilian regions between 2018 and 2022, with the South region presenting the highest mortality rates, whereas the North region showed the lowest burden. These findings reinforce the persistence of regional disparities in asthma-related mortality in Brazil.

Advances in public health policies implemented during the period, such as expanding access to medicines through the Popular Pharmacy Program, strengthening primary care in asthma management in the SUS, standardizing clinical protocols, and improving hospital management, represented important progress in combating the disease. However, even with these measures, there was still an increase in the number of deaths from asthma, which highlights the need for greater attention to factors such as treatment adherence, continuity of care, and regional inequalities that may have limited the impact of these strategies.[5-6]

The Coronavirus Disease 2019 (Covid-19) pandemic, which began in March 2020 and was present during the period analyzed in this study, likely contributed to the increase in asthma deaths. The health crisis has posed numerous challenges to health systems around the world, affecting not only the management of Covid-19 itself, but also aggravating pre-existing chronic conditions such as asthma. Individuals with asthma, who are more susceptible to respiratory complications, faced additional difficulties, especially in light of the overload of health services, which compromised access to essential medical care and may have contributed to increased asthma-related hospitalizations and mortality.[25] Although there is no evidence of an increased risk of worsening in people with mild-to-moderate or well-controlled asthma infected with Covid-19, patients with severe and, above all, uncontrolled asthma were more prone to unfavorable outcomes.[25]

Therefore, the results highlight the need to strengthen primary care and monitoring of respiratory diseases, in addition to improving the accuracy of death registration through professional training, standardization of death certificate completion, and better integration between healthcare services and health information systems to support more effective surveillance actions. They also reinforce the importance of integrated actions between epidemiological and environmental surveillance, with the aim of mitigating risks and reducing preventable deaths.

The main strengths of this study include the scope of the time series (2010 to 2023) and the use of official data from the SIM, which allows for the construction of a consistent overview of asthma mortality in the state. The study presents certain limitations that should be considered. As it is an ecological study based on secondary data, it is not possible to establish causal relationships between environmental, socioeconomic, and demographic factors and asthma mortality; furthermore, the possibility of the ecological fallacy must be considered, given that associations observed at the population level cannot be directly extrapolated to individuals. Additionally, the use of secondary databases may be subject to underreporting, incomplete records, and possible misclassification of causes of death. The mortality rates were crude rather than age-standardized, which may affect temporal comparisons in the context of population aging. Another limitation concerns the exclusion of deaths classified as status asthmaticus (ICD-10 J46), which may have contributed to an underestimation of mortality related to severe asthma. Moreover, information on relevant individual and clinical characteristics such as comorbidities, smoking status, disease severity, treatment adherence, and access to health services was not available in the database used and may have influenced mortality outcomes. Finally, direct measures of environmental exposure were unavailable, preventing an assessment of the specific contribution of air pollutants to asthma mortality.

In conclusion, asthma mortality showed a significant increasing trend in Espírito Santo between 2010 and 2023. Deaths were more frequent among women and older adults, with a greater number of deaths observed in the most populous municipalities of the state, particularly those located in the metropolitan region. Most records were classified as unspecified asthma, indicating limitations in the accuracy of cause-of-death certification and in the identification of asthma phenotypes in mortality statistics.

These results underscore the need to strengthen primary care, improve the accuracy of cause-of-death certification, and enhance epidemiological surveillance to prevent avoidable asthma-related deaths.

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Ronaldo José Faria contributed to project management, literature review, drafting of the abstract, introduction, methodology, and discussion, data collection, interpretation and description of results, conclusions, final review, and statistical analysis. **Nicole Milato da Silva Gonçalves** contributed to the literature review, drafting of the abstract, introduction, methodology, discussion, data collection, interpretation and description of results, conclusions, final revision, and statistics. **Marcelo Matieli da Silva Filho** contributed to the literature review, drafting of the abstract, introduction, methodology, discussion, data collection, interpretation and description of results, conclusions, final revision, and statistics. **Patrícia Silva Bazoni** contributed to

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All authors approved the final version to be published and are responsible for all aspects of the work, including ensuring its accuracy and integrity.

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