

SPATIO-TEMPORAL PATTERNS OF MORTALITY FROM DIABETES MELLITUS: A SCOPING REVIEW

PADRÕES ESPAÇO-TEMPORAIS DA MORTALIDADE POR DIABETES MELLITUS: REVISÃO DE ESCOPO

PATRONES ESPACIO-TEMPORALES DE LA MORTALIDAD POR DIABETES MELLITUS: REVISIÓN DE ALCANCE

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Funding: No funding.

Submitted on: 02/06/2026

Approved on: 08/14/2026

Responsible Editors:

 Alexandra Dias Moreira
 Tânia Couto Machado Chianca

ABSTRACT

Objective: to map the spatial and temporal patterns of mortality from diabetes mellitus. **Method:** this is a scoping review conducted in compliance with JBI recommendations and reported in compliance with PRISMA-ScR. The search was conducted in April 2025 in the MEDLINE, BVS, Web of Science, Scopus, LILACS, and EMBASE databases, as well as in the gray literature, with no restrictions on language or time period. **Results:** a total of 12 studies conducted between 2015 and 2024 were included, primarily in Asia and the Americas, with ecological and time-series study designs, using Bayesian modeling and spatial analysis. Significant spatial heterogeneity was identified, with clusters of high mortality in regions with low socioeconomic development. Socioeconomic factors (urbanization and per capita income), environmental factors (increased urbanization, rising mean temperatures, and pollution), demographic factors (countries in the Southern Hemisphere), and behavioral factors (obesity and physical inactivity) were associated with mortality from diabetes mellitus. **Conclusion:** mortality from diabetes mellitus demonstrates heterogeneous spatial and temporal patterns, which demands contextualized interventions and the strengthening of epidemiological surveillance.

Keywords: Diabetes Mellitus; Mortality; Spatio Temporal Analysis; Scoping Review.

RESUMO

Objetivo: mapear os padrões espaciais e temporais da mortalidade por diabetes mellitus. **Método:** trata-se de uma revisão de escopo conduzida conforme as recomendações do JBI e reportada de acordo com o PRISMA-ScR. A busca foi realizada em abril de 2025, nas bases MEDLINE, BVS, Web of Science, Scopus, LILACS, EMBASE e na literatura cinzenta, sem restrição de idioma ou período. **Resultados:** foram incluídos 12 estudos realizados entre 2015 e 2024, predominantemente na Ásia e nas Américas, com delineamentos ecológicos e de séries temporais, utilizando modelagem bayesiana e análise espacial. Identificou-se significativa heterogeneidade espacial, com clusters de alta mortalidade em regiões de baixo desenvolvimento socioeconômico. Fatores socioeconômicos (urbanização e renda per capita), ambientais (maior urbanização, aumento da temperatura média e poluição), demográficos (países do hemisfério sul) e comportamentais (obesidade e inatividade física) mostraram associação com a mortalidade por diabetes mellitus. **Conclusão:** a mortalidade por diabetes mellitus apresenta padrões espaço-temporais heterogêneos, o que demanda intervenções contextualizadas e o fortalecimento da vigilância epidemiológica.

Palavras-chave: Diabetes Mellitus; Mortalidade; Análise Espaço-Temporal; Revisão de Escopo.

RESUMEN

Objetivo: mapear los patrones espaciales y temporales de la mortalidad por diabetes mellitus. **Método:** se realizó una revisión de alcance conforme a las recomendaciones de JBI y reportada de acuerdo con PRISMA-ScR. La búsqueda se llevó a cabo en abril de 2025 en las bases de datos MEDLINE, BVS, Web of Science, Scopus, LILACS, EMBASE y en literatura gris, sin restricción de idioma ni de período. **Resultados:** se incluyeron 12 estudios realizados entre 2015 y 2024, predominantemente en Asia y las Américas, con enfoques ecológicos y de series temporales que utilizaron modelado bayesiano y análisis espacial. Se identificó una heterogeneidad espacial significativa, con agrupamientos de alta mortalidad en regiones con bajo desarrollo socioeconómico. Los factores socioeconómicos (urbanización y renta per cápita), ambientales (mayor urbanización, aumento de la temperatura media y contaminación), demográficos (países del hemisferio sur) y comportamentales (obesidad e inactividad física) mostraron asociación con la mortalidad por diabetes mellitus. **Conclusión:** la mortalidad por diabetes mellitus presenta patrones espacio-temporales heterogéneos, lo que demanda intervenciones contextualizadas y el fortalecimiento de la vigilancia epidemiológica.

Palabras clave: Diabetes Mellitus; Mortalidad; Analisis Espacio-Temporal; Revisión de Alcance.

How to cite this article:

Carneiro ACAA, Santos Neto M, Santos Neto AT, Rolim ILTP. Spatio-temporal patterns of mortality from diabetes mellitus: a scoping review. REME - Rev Min Enferm. 2026[cited ____];30: e-1606. Available from: <https://doi.org/10.35699/2316-9389.2026.64300>

INTRODUCTION

Diabetes mellitus (DM) is a chronic health condition characterized by episodes of persistent hyperglycemia caused by changes in insulin secretion and/or action. Type 2 DM is the most prevalent form in the population and is generally associated with insulin resistance and progressive dysfunction of pancreatic beta cells^(1,2).

It is estimated that the global prevalence of DM will reach 588.7 million people in 2024, with projections indicating it will reach 852.5 million by 2050, highlighting the magnitude and growing trend of the disease⁽³⁾. This growing prevalence is driven by a complex intertwining of socioeconomic, demographic, environmental, and genetic factors⁽⁴⁾.

Some of the chronic complications associated with diabetes include diabetic nephropathy, retinopathy, and neuropathy, all of which are strongly related to poor glycemic control. In addition, people with diabetes may experience potentially life-threatening acute complications, such as diabetic ketoacidosis, hyperosmolar hyperglycemic state, and hypoglycemia, all of which are associated with high rates of morbidity and mortality⁽²⁾.

In recent years, advances in geotechnologies and methods of spatial and temporal analysis, such as Joinpoint regression for identifying temporal trends, Moran's Index for detecting autocorrelation and spatial clusters, and Geographically Weighted Random Forest (GW-RF) modeling to capture nonlinear relationships and territorial heterogeneities through machine learning, have allowed for a deeper understanding of the spatiotemporal patterns of occurrence, distribution, and mortality from chronic noncommunicable diseases. This contributes to identifying high-risk areas, emerging trends, and priority regions for intervention regarding these diseases⁽⁵⁾.

Despite the relevance of the theme, the available evidence is fragmented across different methods, geographic contexts, and periods of analysis, which hinders the consolidation of knowledge and the identification of gaps to guide future research. Given this, the consolidation of these spatio-temporal analyses serves as an invaluable strategic tool for health planning and for improving epidemiological surveillance, since the precise identification of the distribution patterns of mortality from DM reveals priority areas for action.

The practical impact of this synthesis resides in its ability to inform the management of public health policies by providing evidence for a more efficient and equitable allocation of financial and human resources. Furthermore, by revealing the specific characteristics of each

region, the mapping enables the targeting of geographically sensitive interventions, as well as the strengthening of actions for the prevention, monitoring, and control of DM in the most vulnerable areas.

Therefore, this review aims to answer the following question: "What is the evidence regarding the spatial and temporal patterns of mortality from DM worldwide?" Thus, this study seeks to map the spatial and temporal patterns of mortality from DM at the global level.

METHOD

This scoping review was conducted in compliance with the JBI recommendations⁽⁶⁾, being reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist⁽⁷⁾. The protocol was registered on the Open Science Framework platform (<https://osf.io/wjr2m/overview>).

Eligibility Criteria

Studies that addressed the research question were included, regardless of publication year or language. The following criteria were considered for study inclusion:

- **Participants:** People whose DM was recorded as the basic or associated cause of death, regardless of age, sex, or other characteristics.
- **Concept:** This review considered studies that analyzed the spatial and temporal distribution of mortality from DM. The primary focus was to identify factors reported in the studies across time and space that may be associated with variations in mortality rates from this health condition. Studies that researched the spatial distribution of DM and its associated factors were also considered, provided they contributed to understanding the spatio-temporal patterns related to mortality from the disease.
- **Context:** No specific geographic delimitation was established, as the review included studies published worldwide.

Types of Sources

This review included primary and secondary studies. Abstracts published at conferences, in journals, or in academic repositories were also included, provided they presented preliminary or final data. Guidelines, manuals,

and editorials were also eligible in case they provided information relevant to the research. Studies were excluded if they did not provide information on mortality attributable to DM, the geolocation or geographic area of the analyzed data, the approach used to assess the spatio-temporal distribution of deaths, or factors associated with mortality. Studies that addressed exclusively clinical or laboratory aspects of DM, without any relation to spatial or temporal analyses or population-level determinants of the disease, were also excluded.

Search Strategy

The objective of this search strategy was to identify published studies as well as relevant texts in other information sources, including the gray literature, given the prominence of the theme. With the assistance of a librarian, a specific search strategy was developed for this study. Initially, the strategy was manually adapted for each database according to its specific characteristics, and the search was conducted on April 22, 2025.

The recommendations for a three-step search process proposed by the JBI were followed⁽⁶⁾. Firstly, a limited search was conducted in the MEDLINE (via PubMed) and Latin American and Caribbean Health Sciences Literature (LILACS) databases. These databases were selected since they contain data covering global and regional scopes, respectively. Subsequently, other descriptors and synonyms from the controlled vocabularies MeSH, DeCS, and Emtree were included to compose the final search strategy. Finally, the search was expanded to other databases, as shown in Figure 1. The following databases were used as sources of evidence: Virtual Health Library (BVS), MEDLINE (via PubMed), Web of Science (WoS), Scopus, Latin American and Caribbean Health Sciences Literature (LILACS), and Excerpta Medica dataBASE (EMBASE). In addition, to broaden the search, gray literature sources were considered, including the American Diabetes Association (ADA), the *Sociedade Brasileira de Diabetes* (SBD), and the International Diabetes Federation (IDF).

Selection of studies and sources of evidence

The retrieved studies were exported to the Rayyan – Intelligent Systematic Review software, which is used to manage and synchronize the references⁽⁸⁾. Initially, all articles found in the research databases were identified, and duplicates were removed.

Following this, a pilot calibration test was conducted, in which a random sample of 25 titles and abstracts

was selected. This preliminary step allowed the review team to align their understanding of the eligibility criteria, identify discrepancies, and consider possible adjustments before the main screening, as recommended by the JBI. The initial screening process showed 84% agreement among the evaluators⁽⁶⁾.

In the next step, two reviewers independently screened the titles and abstracts based on the previously established inclusion criteria. In the event of a disagreement between the reviewers, a third reviewer was consulted to resolve the impasse. The selected articles were submitted for full-text review.

The entire selection process was described in narrative form and supported by the development of a flowchart, in compliance with the PRISMA-ScR guidelines⁽⁷⁾.

Data Extraction

For data extraction, the model proposed by JBI was adapted⁽⁶⁾, following the recommendation that a pilot test be conducted by at least two members of the review team.

The eligible studies included in this scoping review were exported to a spreadsheet containing the following data: a) title; b) authors; c) year of publication; d) country of origin; e) journal; f) objective; g) study type/design; h) population and sample; i) variables of interest, including the year and location of the deaths.

The data extraction from the studies included in this review was conducted by one researcher and subsequently checked by two additional reviewers to verify the consistency and completeness of the recorded information.

The methodological quality of the included studies was not evaluated, as it was not part of the selection criteria; this step is considered optional in scoping reviews.

Data Analysis and Presentation

The extracted data were tabulated and presented using maps (created with the Canva software) and tables, with the main results highlighted in a descriptive manner. The data were also submitted to qualitative content analysis, as proposed by Elo and Kyngäs. Thus, results with similar characteristics were grouped into central thematic domains.

RESULTS

This review included 12 studies published between 2015 and 2024 that researched DM mortality from a

Figure 1 - Database Search Strategy

Database	Search Strategy
Medline/ Pubmed	("diabetes mellitus"[MeSH Terms] AND "spatio temporal analysis"[MeSH Terms]) OR "analys*s spatio temporal"[Title/Abstract] OR "spatio temporal analys*s"[Title/Abstract] OR "spatial temporal analys*s"[Title/Abstract] OR "analys*s spatial temporal"[Title/Abstract] OR "tempo-ral analys*s spatial"[Title/Abstract] OR "spatiotemporal analys*s"[Title/Abstract] OR "analys*s spatiotemporal"[Title/Abstract] OR "space time geography"[Title/Abstract] OR ("geograph*" [All Fields] AND "Space-Time"[Title/Abstract]) OR "space time geograph*" [Title/Abstract]
Web of Science	TS=(Diabetes Mellitus) AND (((((((((TS=(Spatio-Temporal Analysis)) OR TS=(Analys*s, Spatio-Temporal)) OR TS=(Spatio- Temporal Analys*s)) OR TS=(Spatial Temporal Analys*s)) OR TS=(Analys*s, Spatial Temporal)) OR TS=(Temporal Analys*s, Spatial)) OR TS=(Spatiotemporal Analys*s)) OR TS=(Analys*s, Spatiotemporal)) OR TS=(Space-Time Geography)) OR TS=(Geograph*, Space-Time)) OR TS=(Space-Time Geograph*)
BVS	("Diabetes Mellitus" OR "Diabète") AND ("Análise Espaço-Temporal" OR "Spatio-Temporal Analysis" OR "Análisis Espacio-Temporal" OR "Analyse spatio-temporelle")
EMBASE	'diabetes'/exp OR 'diabetes' OR 'diabetic'/exp OR 'diabetic' OR 'diabets'/exp OR 'diabets' OR 'unspecified diabetes mellitus'/exp OR 'unspecified diabetes mellitus' OR 'diabetes mellitus'/exp OR 'diabetes mellitus' AND 'space-time clustering' OR 'spatial temporal analysis' OR 'spatio- temporal analysis' OR 'spatiotemporal analysis'
Scopus	TITLE-ABS-KEY (diabetes AND mellitus) AND TITLE-ABS-KEY (spatio-temporal AND analysis)
LILACS	("Diabetes Mellitus" OR "Diabète") AND ("Análise Espaço-Temporal" OR "Spatio-Temporal Analysis" OR "Análisis Espacio-Temporal" OR "Analyse spatio-temporelle")
ADA/SBD/IDF	("Diabetes mellitus") and ("Spatio-Temporal Analysis")

Source: Prepared by the authors (2026).

spatial and temporal perspective in varying geographical and population contexts⁽⁹⁻²⁰⁾. Of these, 50% (n = 6)^(9,15,16,18-20) were conducted in Asia, primarily in China^(9,16,18-20). In the Americas, five studies were identified (41.7%)^(10-13,17), of which three^(10,11,17) analyzed data from Latin America and two^(12,13) were conducted in the United States. In addition, one study (8.3%)⁽¹⁴⁾ provided global coverage, encompassing 204 countries.

Most of the studies (76.9%) were published in open-access journals, with predominantly ecological study designs (n = 9; 75%)^(9-11,13,14,16-19), cross-sectional study (n = 1; 8%)⁽¹²⁾, geographic epidemiological study with spatio-temporal analysis and spatial modeling (n = 1; 8%)⁽²⁰⁾, and editorial (n = 1; 8%)⁽¹⁵⁾. The selection process is summarized in Figure 2. Although the main focus of the included studies was mortality from DM, some studies addressed the prevalence of the disease and its risk factors, contributing to an understanding of the spatial determinants associated with DM.

Figure 3 illustrates the geographic distribution of the studies and the temporal trend in publications. A gradual increase in the number of studies can be observed starting in 2018, coinciding with advances in geoprocessing and spatial epidemiology tools applied to public health.

On a global scale, the highest concentration of studies occurred in China (n = 5), followed by the United

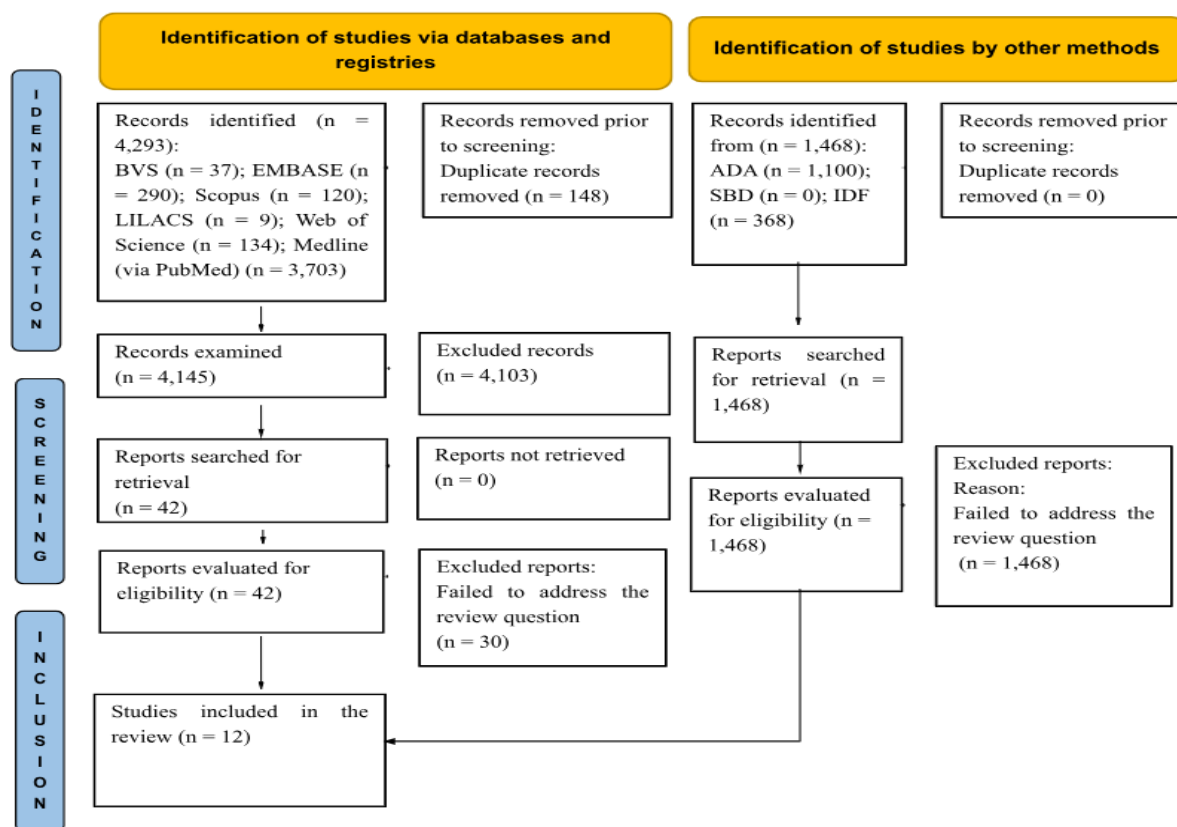
States (n = 2) and multicenter publications with international scope (n = 2). Studies were also identified in Ecuador (n = 1), Brazil (n = 1), Argentina (n = 1), and South Korea (n = 1).

At the bottom of Figure 3, the time axis represents the publication period of the studies, spanning from 2015 to 2024. Each line indicates the time interval covered or analyzed by each study. Of particular note are the publications issued between 2021 and 2024, highlighting the growing scientific interest in spatio-temporal patterns related to DM in recent years.

Figure 4 provides a summary of the methods and main results of the included studies. There was a prevalence of studies focused on mortality from DM, although some studies also analyzed the prevalence of the disease and associated behavioral risk factors^(13,15). The samples varied widely across the studies, encompassing analyses of 161 Chinese municipalities⁽⁹⁾ up to global data from 203 countries⁽²⁰⁾, with observation periods between 1990 and 2020.

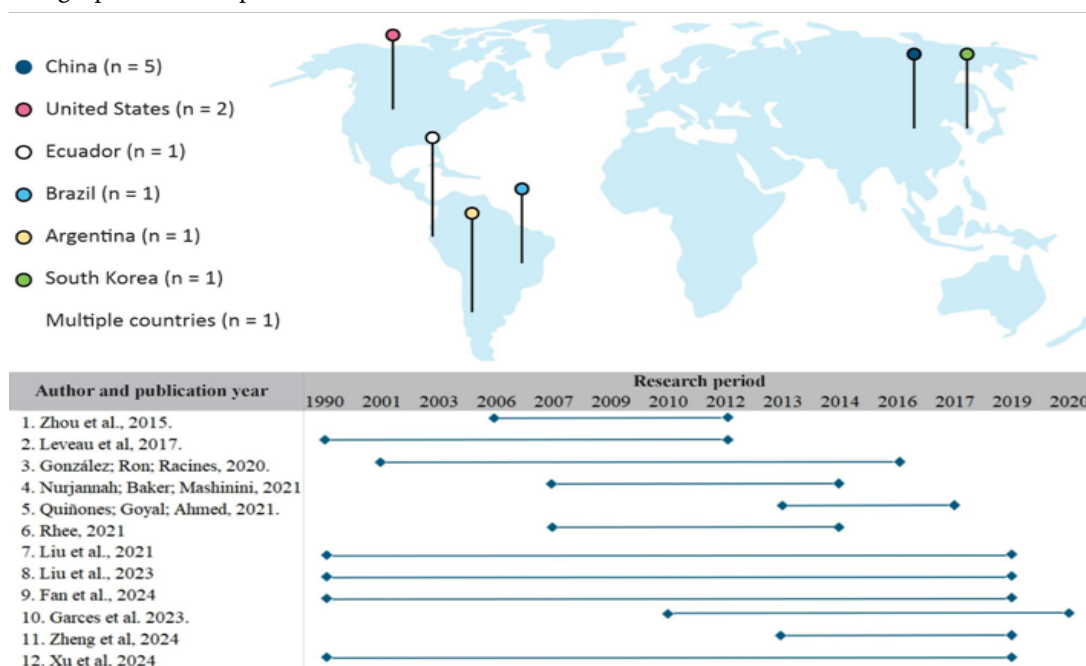
Socioeconomic factors were the most frequently researched (92.3%), followed by environmental and climatic factors (61.5%), demographic factors (53.8%), and behavioral factors (46.1%). Among the most frequently cited variables were urbanization, per capita income,

Figure 2 - Flowchart of the study selection process. .



Source: Adapted from the PRISMA-ScR Flowchart.⁷

Figure 3 – Geographic and temporal distribution of the included studies.



Source: Compiled by the authors, 2026.

population density, air pollution, mean temperature, physical inactivity, and obesity^(9,14,18,20).

With regard to the main findings, significant spatial heterogeneity was observed in the distribution of mortality from DM. In China, the highest mortality rates were found in the Northeast and Northwest regions, while the Southern areas had lower rates⁽⁹⁾. This distribution was associated with factors such as urbanization, high mean body mass index, mean annual temperature, and levels of air pollution⁽¹⁶⁾. In the global context, clusters of high mortality were identified in island and low-income countries, such as Fiji, Kiribati, and Trinidad and Tobago, highlighting negative correlations between mortality and levels of air pollution and alcohol consumption. These results suggest that economic and environmental factors have varying impacts depending on a country's level of development⁽²⁰⁾.

In the studies conducted in the Americas, the high mortality rates in Northern Argentina were associated with the level of education and poor sanitary infrastructure⁽¹⁰⁾, meanwhile, in Ecuador, there was a 3.2% annual increase in mortality from T2DM between 2010 and 2020, particularly among older women and urban populations⁽¹¹⁾. In Brazil, remarkable regional inequalities stood out, with higher mortality rates in the Northeast and Midwest regions, correlated with social vulnerability and low coverage of primary health care⁽¹⁷⁾.

In addition, over the past decade, there has been a rising trend in mortality associated with urbanization and population aging^(16,17), while other studies reviewed have indicated a reduction or stabilization in mortality rates in areas with better access to healthcare and prevention programs^(15,18). In contrast, the nutritional transition and the expansion of small and medium-sized cities have been associated with an increase in the burden of T2DM, particularly in middle-income countries^(13,17).

DISCUSSION

This review showed that mortality from DM has a heterogeneous spatial distribution, characterized by the formation of high-risk clusters in regions with less favorable socioeconomic conditions. This pattern was observed in different geographic contexts, including countries in Latin America, Asia, and regions worldwide, indicating that the occurrence of deaths is not randomly distributed across the territory. The results corroborate previous evidence obtained through spatial analyses based on Moran's Index and other spatial autocorrelation techniques, which

demonstrate the influence of the territorial context on the distribution of mortality from DM^(10,11,15,17).

The concentration of areas with higher mortality rates in regions characterized by social inequalities suggests that the determinants of disease go beyond individual biological factors, reflecting structural conditions related to access to healthcare, income, education, and infrastructure. In Argentina, for example, the highest mortality rates were found in areas with unfavorable socioeconomic indicators, while in Brazil, social vulnerability and lower primary health care coverage were associated with an increase in deaths from DM^(10,17). Similarly, studies conducted in China identified higher mortality rates in more urbanized regions, which were associated with factors such as high body mass index, mean annual temperature, and exposure to air pollution^(9,16).

In addition to the spatial dimension, the studies reviewed demonstrated significant temporal changes in mortality from DM. Although some localities have shown a reduction or stabilization in rates over the years, particularly in contexts where access to healthcare services has expanded and prevention strategies have been strengthened, the overall trend still points to a stable or increasing disease burden^(14,18,21-23). This scenario is particularly concerning in countries with low and medium levels of socioeconomic development, where rapid urbanization, population aging, and changes in lifestyle contribute to the increase in risk factors associated with DM⁽²⁴⁾.

The findings also underscore the importance of environmental determinants in the dynamics of mortality from DM. Prolonged exposure to air pollution from fine particulate matter (e.g., PM_{2.5}) and suboptimal temperatures have been associated with an increase in the disease burden in different regions of the world^(14,16). These findings acquire greater significance in light of the climate changes observed in recent decades, given that populations living in more vulnerable areas tend to have a lower capacity to adapt to extreme environmental events and reduced access to healthcare services capable of mitigating their effects. Thus, environmental factors should be understood as relevant determinants of health inequalities related to DM⁽²⁵⁾.

Another recurring aspect in the studies was the influence of behavioral factors. Obesity and physical inactivity were frequently associated with increased mortality and the overall burden of disease, especially in regions with lower levels of socioeconomic development^(13,18). Although these factors are often treated as individual choices, the results suggest that their distribution is also related to the characteristics of the urban environment,

Figure 4 – Characteristics and main findings of studies on mortality from DM

Author (year) / Country	Study Design	Unit of analysis	Main findings
Zhou et al. (2015) China	Ecological	Nationwide; urban and rural areas	Higher mortality among women; persistent regional disparities; increased urbanization, BMI, and mean temperature are associated with higher mortality.
Leveau et al. (2017) Argentina	Ecological	Departments; adults aged 34 and older; by sex	Clusters of high premature mortality in the north-central region; results suggest the influence of policies and access to services.
González; Ron; Racines (2020) Equador	Mixed ecological	Provincial; both sexes	57,788 deaths (55.1% women); declining mortality trends in Andean provinces and rising trends in coastal areas.
Nurjannah; Baker; Mashinini (2021) EUA	Retrospective, observational, spatio-temporal ecological study	School Districts in Michigan	A slight decline in mortality; persistence of high-high clusters; identification of priority hotspots for school-based interventions to prevent DM.
Quiñones; Goyal; Ahmed (2021) EUA	Spatial ecological	204 countries; 1990–2019	Obesity and physical inactivity as the main predictors; strong spatial non-stationarity; the need for localized prevention strategies.
Liu et al. (2021) Global	Ecological/retrospective	204 países; 1990–2019	A substantial increase in the burden of T2DM attributable to fine airborne particles with a diameter of up to 2.5 micrometers (PM2.5); greater impact on older people, men, and regions with low-to-medium development indexes.
Rhee (2021) Coreia do Sul	Editorial	National	Evidence of the non-random nature of the spatial distribution of DM; the usefulness of spatio-temporal analyses for public policy; high national prevalence of DM.
Liu et al. (2023) China	Time-Series ecological study	Global; 1990–2019	Deaths attributable to rising temperatures; the impact of heat exceeded that of cold in less developed regions; higher risk among older people and men.
Garces et al. (2023) Brasil	Ecological	Municipal; national	Growing trend and spatial heterogeneity; influence of the Social Vulnerability Index and ESF coverage.
Fan et al. (2024) China	Ecological/retrospective	Global; up to 2050	Projections indicate a decline in the age-standardized mortality rate, but a continued increase in disability-adjusted life years due to DM.
Zheng et al. (2024) China	Ecological	Provincial; older people	Mean temperature and humidity associated with mortality from T2DM
Xu et al. (2024) Global	Spatio-temporal geographical epidemiology	203 countries; 1990–2019	BMI, smoking, and indoor air pollution are associated with increased overall mortality; high regional disparities; higher healthcare spending and a greater number of medical doctors are associated with lower mortality.

Source: Prepared by the authors (2026).

living conditions, and opportunities for access to adequate nutrition and physical activity. This finding reinforces the need for interventions that go beyond approaches focused exclusively on the individual, considering the social and territorial contexts in which people live⁽²⁶⁾.

In addition, one point identified in this review concerns the contribution of spatial and temporal analysis methods to understanding mortality from diabetes. Tools such as Joinpoint regression, Bayesian modeling, spatial

cluster analysis, and geographically weighted models have allowed for the identification of patterns that would be difficult to observe through conventional epidemiological analyses^(5,27,28). In addition to identifying priority areas for intervention, these methodologies enable the monitoring of trends over time and provide an understanding of how environmental, socioeconomic, and behavioral factors interact to determine mortality⁽²⁷⁾.

From the perspective of public policy, the findings underscore the need for territory-specific strategies to address DM. Identifying high-risk areas can inform the planning of public health surveillance measures, the organization of services, and a more equitable distribution of available resources. In this context, primary health care performs a vital role in the prevention, monitoring, and control of the disease, especially in socially vulnerable regions.

For nursing, the findings highlight the potential of spatial analyses as tools to support the planning of care and surveillance initiatives. Identifying areas with the highest concentration of deaths from DM can support the organization of active case-finding, the monitoring of people with diabetes, and the implementation of educational initiatives targeting local needs. Thus, the use of spatial information strengthens evidence-based health planning and contributes to reducing inequalities related to the care and management of the disease.

LIMITATIONS

By synthesizing complex spatial analysis methodologies and multiple determinants associated with mortality from DM, this review provides a comprehensive overview of the spatio-temporal distribution of the disease, helping to fill gaps in the literature and strengthen health planning efforts. However, the prevalence of ecological study designs among the included studies must be considered, as this implies a risk of ecological fallacy and limits the extrapolation of the observed associations from the population level to the individual level.

In addition, potential publication, language, and geographic representation biases have been identified, as evidenced by the concentration of studies in countries in Asia and the Americas. In contrast, there was a scarcity of research in several socially vulnerable regions, which may limit the global understanding of mortality patterns from DM.

In view of this scenario, it is recommended that future research expand the body of evidence in regions that remain underrepresented and invest in studies with individualized and spatially contextualized approaches. Such initiatives could contribute to a deeper understanding of the determinants of mortality from DM and to the improvement of strategies for surveillance, prevention, and control of the disease on a global scale.

CONCLUSION

Mortality from DM exhibits heterogeneous spatio-temporal patterns, characterized by high mortality in regions with lower socioeconomic development and in contexts marked by rapid urbanization, social vulnerability, adverse environmental conditions, and demographic changes. The studies analyzed demonstrate that socioeconomic, environmental, and behavioral factors interact in complex manner in determining the risk of death from DM, highlighting that the distribution of deaths is not random across the territory, but instead follows specific structural dynamics.

Furthermore, a rising or stable trend in mortality was observed in most of the scenarios evaluated, with projections indicating that the disease burden will remain stable or increase in the coming decades, especially in low- and middle-income countries. These findings reinforce the need to expand the use of spatial and temporal analyses in monitoring DM, improve surveillance systems, and develop territory-sensitive interventions that consider regional inequalities.

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