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Temporal trends in prostate cancer incidence, mortality, and survival in the health regions of Sergipe, Brazil, 1996-2022

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ABSTRACT

Objective: to examine the temporal trends of these indicators across the state's health regions to provide evidence that supports improvements in public policies and actions aimed at disease control.
Material and methods: Ecological study conducted in Sergipe state, Brazil. We used anonymized data on malignant prostate neoplasms (ICD-10 C61) from the Aracaju Cancer Registry (ACR) for 1996–2017. Mortality data were obtained from the Mortality Information System (SIM) for 1996–2022. Age-specific and age-standardized incidence and mortality rates were calculated. The Mortality-to-Incidence Ratio (MIR) and its complement (1–MIR) were used as indirect indicators of five-year survival. Temporal trends were assessed using Joinpoint regression (version 5.3.0), estimating APC, AAPC and 95 % confidence intervals using Monte Carlo permutation tests.
Results: A total of 10,133 prostate cancer cases were recorded from 1996 to 2017. The age-standardized incidence rate increased from 42.4 per 100,000 (1996–2005) to 76.8 per 100,000 (2006–2012), decreasing slightly to 72.3 per 100,000 (2013–2017). The overall annual increase was 6.63 %, with Aracaju showing 6.85 %. Declines occurred only in Nossa Senhora do Socorro from 2007 to 2017 (APC: –1.85; 95 %CI: –3.59; –0.26). Between 1980–2022, age-standardized mortality increased 4.20 % annually (95 %CI: 3.35–4.81), with marked rises in Estância (7.20 %), Propriá (6.02 %), Lagarto (5.53 %), Nossa Senhora da Glória (4.83 %), and Itabaiana (2.89 %). MIR-based survival declined from 76.57 % (1996–1999) to 71.27 % (2015–2017), with increased MIR among adults aged 75 + , decreasing MIR among individuals aged 15–54—especially in the capital—and increases across all age groups in Propriá.
Conclusion: Prostate cancer in Sergipe demonstrates significant regional and age-related disparities in incidence, mortality, and survival. Rising incidence and mortality, along with adverse MIR trends, underscore the need for targeted health policies to improve early detection, treatment access and long-term outcomes.

1. Introduction

Prostate cancer is a major global public health concern, with wide differences in incidence, mortality, and survival rates based on sociodemographic factors and a country's level of development. It is the most common malignant tumor among men in many parts of the world and one of the leading causes of cancer-related deaths in this population [1].

Inequalities in disease occurrence reflect not only biological and genetic factors but also differences in access to health services, screening policy implementation, and socioeconomic conditions. Racial disparities are well documented: between 2014 and 2018 in the United States, the average incidence rate among Black men was 73 % higher than among

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White men, and mortality was about twice as high [2].

The Human Development Index (HDI) also significantly impacts the epidemiological profile of prostate cancer. From 2000–2019, high-HDI countries reported incidence rates nearly twice as high as those in low-HDI countries. Conversely, mortality rates exhibited a negative correlation with HDI [3]. This pattern emphasizes the importance of early diagnosis and access to effective treatments in lowering mortality.

Mortality patterns from cancer typically reflect past incidence and survival rates, providing a long-term view of the disease's impact [4]. In Brazil, a cohort study reported a cancer-specific survival rate of 75 % at 160 months, with decreases as age increased: 75 % among patients aged 70–79 years and 69 % among those aged 80 or older. These results emphasize that many patients live with the disease for long periods, often under active surveillance [5].

Globally in 2022, the age-standardized incidence rate was 29.4 cases per 100,000 men, with higher rates reported in France (82.3 per 100,000), Brazil (76.3 per 100,000), and the United States (75.2 per 100,000). The global mortality rate of 7.3 deaths per 100,000 men was significantly higher in Nigeria (27.9 per 100,000) and Brazil (13.5 per 100,000) [6].

Prostate cancer has become one of the most significant tumors among men, due to the increases observed in recent decades and marked regional differences in its incidence and mortality rates. While state-level analyses provide an overall epidemiological profile, they may conceal substantial intra-state heterogeneity related to socioeconomic conditions, healthcare organization, and access to diagnostic and treatment services. Understanding variations at the health-region level is therefore crucial for guiding screening, diagnosis, and treatment policies that are responsive to local contexts and the capacity of regional health systems. The spatial and temporal approach enables a more precise assessment of how cancer control strategies have evolved over time within distinct territorial and organizational settings of the health system. Therefore, this study aimed to examine the temporal trends of these indicators across the state's health regions to generate evidence that supports targeted public policies and region-specific actions for prostate cancer control.

2. Material and methods

This was an ecological study. This research was carried out in Sergipe, the smallest state in Brazil, located in the Northeast region and covering a total area of 21,938.188 km^2. The state includes 75 municipalities divided into seven administrative health regions (HR), with an estimated population of 2.2 million—making up about 1.1 % of Brazil's total population—and an average population density of 100.74 inhabitants per km^2. The population consists of 48.2 % males and 51.8 % females, with life expectancies of 72 and 79 years, respectively [7].

Sergipe's Human Development Index is 0.702, with its capital, Aracaju (population approximately 672,614), being the only municipality classified as having a high HDI (0.770) [7]. Aracaju excelled in access to healthcare, education, social welfare services, formal employment, and urban infrastructure. In contrast, many rural municipalities continued to face structural disadvantages, especially related to limited coverage of the Family Health Strategy (FHS), which is the main entry point to Brazil's public healthcare system.

In Brazil, Health Regions are territorial units composed of neighboring municipalities that share social, economic, cultural, and infrastructural characteristics and are organized to integrate the planning, coordination, and delivery of healthcare services within the Unified Health System (SUS). In the state of Sergipe, the current configuration of Health Regions was established through state-level planning instruments and intergovernmental agreements, resulting in seven Health Regions that serve as the primary organizational units for health policy implementation and service provision.

The Health Region of Aracaju, which includes the state capital and its metropolitan surroundings, concentrates the largest population (approximately 855,000 inhabitants) and the most developed healthcare network, including specialized and referral services. The Regions of Nossa Senhora do Socorro (~353,000 inhabitants), Estância (~237,000 inhabitants), Itabaiana (~261,000 inhabitants), and Lagarto (~265,000 inhabitants) represent intermediate population sizes and mixed urban–rural contexts. In contrast, the Regions of Nossa Senhora da Glória (~177,000 inhabitants) and Propriá (~151,000 inhabitants) have smaller populations and predominantly rural characteristics [7].

2.1. Study population and data sources

The study used anonymized data from patients diagnosed with primary malignant prostate neoplasms (International Classification of Diseases, 10th Revision – ICD-10, topography code C61), obtained from the Aracaju Cancer Registry (ACR) for the period 1996–2017. Tumor morphologies were classified according to the International Classification of Diseases for Oncology, Third Edition (ICD-O-3). The ACR, established in 1998, retrospectively compiled data starting in 1996, initially limited to cases diagnosed within the city of Aracaju. Although the registry systematically recorded all confirmed cancer diagnoses—regardless of patients' municipality of residence—it was originally designed to represent the population of the state capital. Since 2022, coordinated efforts involving academic research partnerships aimed to consolidate and validate data at the state level, expanding the registry's geographic coverage beyond Aracaju. For prostate cancer (C61), incidence data have been thoroughly validated for the entire state of Sergipe covering the period from 1996 to 2017. All male cases and deaths aged 15 years or older were eligible for inclusion in the analyses.

Mortality data were obtained from the Mortality Information System (SIM) (https://datasus.saude.gov.br/mortalidade-desde-1996-pela-cid-10), covering deaths attributed to prostate cancer from 1996 to 2022. Managed by the Brazilian Ministry of Health, SIM is publicly accessible through the Department of Informatics of the Unified Health System (DATASUS). Since its implementation in the late 1970s, the system has experienced ongoing improvements in coverage, data quality, and the completeness of death certification. Over the last two decades, consistent investments in data standardization, training of health professionals, and the expansion of death investigation committees have improved the overall reliability of mortality statistics [8,9]. The analysis periods for incidence (1996–2017) and mortality (1996–2022) were chosen based on the availability of complete and validated datasets.

2.2. Statistical analyses

Age-specific incidence and mortality rates were calculated by dividing the number of prostate cancer cases and deaths by the corresponding population counts obtained from the national censuses of 1991, 2000, and 2010, supplemented by intercensal annual population estimates from the Brazilian Institute of Geography and Statistics (IBGE). Age groups were predefined as 15–54, 55–64, 65–74, 75 + , and all ages, following the International Cancer Survival Standards (ICSS), to ensure comparability across populations [10]. Age-standardized rates were calculated by direct standardization of age-specific rates to the World Standard Population [11].

The Mortality-to-Incidence Ratio (MIR) was calculated by dividing the number of deaths by the number of newly diagnosed prostate cancer cases within specific time periods. Its complementary metric, (1 – MIR), served as an indirect estimate for five-year survival when comprehensive survival data was not available [12]. However, MIR-based survival estimates should be interpreted carefully, as they can be influenced by confounding factors such as competing causes of death, diagnostic differences, disparities in treatment access, and demographic variations [12–16].

Temporal trends were analyzed using the Joinpoint Regression Program, version 5.3.0. Calendar year served as the independent variable, while age-standardized incidence and mortality rates were treated as dependent variables. The maximum number of Joinpoint was five. The Annual Percent Change (APC) calculated the rate variation within each trend segment, and the Average Annual Percent Change (AAPC) offered an overall summary of temporal patterns throughout the study period. The option "First-order autocorrelation estimated from the data" was used to account for serial correlation. Statistical significance was determined through Monte Carlo permutation tests with 95 % confidence intervals and 5 % significance [17].

2.3. Ethics statement

This study was approved by the Research Ethics Committee of the Federal University of Sergipe (UFS) under reference number 5.531.966. All procedures followed relevant ethical guidelines and regulatory standards. To protect confidentiality, only de-identified databases were used, for which obtaining individual informed consent was not applicable. An exemption from informed consent was requested and approved by the Ethics Committee, in accordance with Resolution No. 466 of December 2012 issued by the Brazilian Ministry of Health.

3. Results

Between 1996 and 2017, there were a total of 10,133 reported prostate cancer cases in Sergipe, Brazil. The age-standardized incidence rate (ASIR) increased from 42.4 per 100,000 men during 1996–2005–76.8 per 100,000 in 2006–2012, then slightly declined to 72.3 per 100,000 in 2013–2017.

Table 1 shows the results of the average temporal trend in incidence rates in Sergipe. The state experienced an annual increase of 6.63 % in the age-standardized incidence rate. All health regions displayed increases in age-standardized incidence, with Aracaju prominent for its annual growth of 6.85 %.

Table 2 shows the results of the average trend over time in mortality rates by age group and in the age-standardized mortality rate across Sergipe's health regions. From 1980–2022, the state experienced an annual increase of 4.20 % (95 % CI: 3.35; 4.81) in the age-standardized mortality rate. Similarly, the regions of Aracaju had a 1.41 % increase (95 % CI: 0.10; 2.84), Estância 7.20 % (95 % CI: 5.27; 9.18), Glória 4.83 % (95 % CI: 3.44; 6.48), Itabaiana 2.89 % (95 % CI: 1.12; 4.48), Lagarto 5.53 % (95 % CI: 3.80; 7.02), and Propriá 6.02 % (95 % CI: 3.24; 8.86) annually.

Table 3 shows the trend in prostate cancer incidence, age-adjusted and stratified by the age groups studied. There was an increase in the age-adjusted incidence rate from 1996 onward across all age groups and health regions. A decrease trend was observed only in the region of Nossa Senhora do Socorro during the period 2007–2017 (APC: −1.85*; 95 %CI: −3.59; −0.26). The regions of Aracaju, Itabaiana, Lagarto, and the state capital also experienced decreases from 2006 to 2017.

Table 4 shows all the results of the temporal trend analysis by age group and health region. The trend of prostate cancer mortality in Sergipe varied across different health regions. Throughout the state, increases were noted in the 55–64-year age group (APC: 3.45 %; 95 %CI: 2.09–4.85) and the 65–74-year age group (APC: 6.60 %; 95 %CI: 4.71–51.44) until 2009. The Capital experienced a decrease in the 15–54-year age group between 1982 and 2021 (APC: −2.37 %; 95 %CI: −4.51; −0.17). In Estância, there was an increase in the age-standardized mortality rate (APC: 7.20 %; 95 %CI: 5.27–9.18), with a peak between 2001 and 2004 (APC: 92.44 %; 95 %CI: 26.24–130.54). Lagarto showed an increase in the 65–74-year age group from 1985 to 2022 (APC: 4.14 %; 95 %CI: 1.42–7.13), while Propriá maintained growth until 2009 (APC: 9.74 %; 95 %CI: 7.09–23.47).

Table 5 shows the mortality-to-incidence ratio (MIR) based on health region and age group. The survival rate in Sergipe gradually declined from 76.57 % in 1996–1999–71.27 % in 2015–2017, except for older adults aged 75 and above, who experienced an increase in the MIR. A progressive increase in the MIR over the five-year periods was also noted for the age group over 75 in most health regions. Notably, there was a five-year decrease in the MIR among younger individuals aged 15–54 years, particularly in the state capital. An increase in the ratio was seen across all age groups in the Propriá health region.

4. Discussion

The current study found a consistent rise in prostate cancer incidence and mortality in Sergipe over the studied period. Incidence rates increased across nearly the entire region, reflecting both expanded diagnostic capabilities and potential differences in reporting coverage and quality. Meanwhile, mortality rose in several areas, especially in inland regions, while some locations, like the capital, showed stable or decreasing trends. The analysis of the mortality-to-incidence ratio indicated a decrease in survival probability statewide, with increases among older adults, suggesting possible regional and age-related disparities regional and age-related disparities in access to early diagnosis and treatment.

In this study, the health regions of Lagarto, Itabaiana, and Estância showed decreases in incidence among the 75 + age group. In Spain, from 1975 to 2013, only men aged 75 and older experienced a decline in incidence [18]. Geographic barriers [19], lack of awareness, and negative perceptions and attitudes about one's own health and age may contribute to this decline [20]. These findings emphasize the need to strengthen health policies targeted at the elderly population, ensuring adequate access to screening and early diagnosis, and improving epidemiological surveillance systems in these regions. Although decreases in incidence may initially indicate improvements in disease control, such findings should be interpreted carefully, as in contexts of healthcare inequalities, they may reflect decreased case detection rather than a true drop in occurrence. Therefore, the apparent decrease in some regions may also reflect structural and operational limitations in screening and reporting services. In addition, those findings should be interpreted within the context of demographic and epidemiological transitions. Improvements in socioeconomic conditions, healthcare access, and disease management have contributed to increased life

Table 1
Average Annual Percent Change (AAPC) and 95 % confidence intervals (95 %CI) in age-adjusted prostate cancer incidence per 100,000 inhabitants and for the age groups 15–54, 55–64, 65–74, and 75 years and over in the health regions of Sergipe, Brazil, 1996–2017.

Region	JP	ASR	(95 %CI)	15–54	(95 %CI)	55–64	(95 %CI)	65–74	(95 %CI)	75 +	(95 %CI)
Sergipe	1996–2017	6.63*	(5.00; 8.99)	6.95*	(5.62; 9.55)	11.00*	(8.07; 16.51)	4.92*	(3.85; 6.76)	3.83*	(2.41; 6.14)
Capital	1996–2017	6.49*	(5.89; 7.33)	6.85*	(5.58; 8.60)	11.18*	(10.15; 12.61)	5.89*	(4.59; 7.55)	3.84*	(2.27; 5.62)
Aracaju	1996–2017	6.85*	(6.05; 8.41)	6.83*	(5.40; 9.12)	11.01*	(8.47; 16.02)	4.77*	(3.65; 6.69)	3.82*	(2.26; 5.89)
Estância	1996–2017	5.46*	(4.56; 7.27)	-	-	-	-	5.31*	(4.33; 7.18)	4.07*	(2.77; 6.30)
Glória	1996–2017	5.75*	(4.90; 7.18)	-	-	-	-	5.48*	(4.42; 7.12)	4.47*	(3.34; 7.05)
Itabaiana	1996–2017	6.53*	(4.88; 9.10)	-	-	11.03*	(8.29; 16.31)	4.91*	(3.88; 6.82)	3.65*	(2.44; 5.78)
Lagarto	1996–2017	5.40*	(4.47; 7.22)	-	-	-	-	4.95*	(3.88; 6.88)	3.91*	(2.56; 6.56)
Propriá	1996–2017	5.42*	(4.51; 7.05)	-	-	-	-	5.20*	(4.16; 7.05)	3.97*	(2.64; 6.76)
Socorro	1996–2017	4.77*	(3.93; 6.21)	-	-	-	-	4.92*	(3.74; 7.09)	4.17*	(2.74; 6.71)

Note: ASR: Age Standard Rate; JP: Joinpoint segment; * p < 0,05

Table 2
Average Annual Percent Change (AAPC) and 95 % confidence intervals (95 %CI) for age-adjusted prostate cancer mortality per 100,000 inhabitants and for the age groups 15–54, 55–64, 65–74, and 75 years and over in the health regions of Sergipe, Brazil, 1980–2022.

Region	JP	ASR	(95 %CI)	15–54	(95 %CI)	55–64	(95 %CI)	65–74	(95 %CI)	75 +	(95 %CI)
Sergipe	1980–2022	4.20*	(3.35; 4.81)	0.00	(-1.77; 1.83)	3.45*	(2.09; 4.85)	3.98*	(0.88; 7.65)	4.59*	(3.44; 5.42)
Capital	1980–2022	0.55	(-0.98; 2.17)	-2.37*	(-4.51; −0.17)	-1.01	(-2.84; 0.85)	-0.37	(-1.62; 0.88)	1.74*	(0.59; 2.89)
Aracaju	1980–2022	1.41*	(0.10; 2.84)	-2.08	(-4.29; 0.30)	0.10	(-1.53; 1.80)	0.65	(-0.48; 1.79)	1.51	(-0.04; 3.28)
Estância	1999–2022	7.20*	(5.27; 9.18)	-3.84	(-7.93; 0.52)	0.29	(-1.86; 3.00)	2.52	(-0.40; 5.63)	4.12*	(2.18; 5.69)
Glória	1999–2022	4.83*	(3.44; 6.48)	-		-0.38	(-7.77; 7.19)	0.15	(-2.03; 2.59)	7.68*	(4.02; 11.67)
Itabaiana	1999–2022	2.89*	(1.12; 4.48)	-3.20*	(-4.74; −1.83)	-3.19	(-6.21; 0.71)	3.46	(-2.09; 9.22)	2.55*	(0.77; 4.30)
Lagarto	1999–2022	5.53*	(3.80; 7.02)	-		-1.54	(-5.93; 3.64)	4.14*	(1.42; 7.13)	4.62*	(2.95; 6.34)
Propriá	1999–2022	6.02*	(3.24; 8.86)	-		-1.42	(-3.36; 0.95)	0.85	(-1.51; 3.38)	2.88*	(0.21; 5.44)
Socorro	1999–2022	-3.38	(-5.52; 0.55)	-2.12	(-6.20; 2.58)	-4.24*	(-5.88; −0.94)	-3.07	(-5.97; 0.66)	-6.19*	(-9.40; −2.06)

Note: JP: Joinpoint segment; ASR: Age Standard Rate; * $p < 0,05$

expectancy and substantial reductions in mortality from cardiovascular conditions [21].

In this study, a significant rise in incidence was observed at the start of the time series across all age groups and most health regions. Similar findings were reported in another study conducted within the state, which documented an increase from 1996 to 2007 [22]. Additionally, another investigation conducted in Sergipe reported an average annual increase of 3.5 % (95 % CI: 1.6; 5.3) between 1996 and 2017 [23]. One explanation for this initial growth is the implementation of the Population-Based Cancer Registry (RCBP) in the state, which began in 1996 [24]. The RCBP was adopted across the country, first in São Paulo and Recife in the 1960s and later expanding to other cities [25]. The system's implementation occurs gradually, and adaptations are necessary to improve reporting processes, which tend to become more efficient over time [26]. Therefore, the increase observed in this study may reflect a shift from underreporting to greater diagnostic accuracy and improved registry practices, underscoring the importance of robust health information systems for effective monitoring of neoplasms. Additionally, the rise in PSA testing may have contributed to this increase, as the test began to be widely disseminated and adopted for early cancer detection [27]. Moreover, the initial rise in incidence could partially be due to opportunistic PSA screening and the resulting overdiagnosis of clinically indolent tumors, a phenomenon known as screening effect and overdiagnosis [28,29] which tends to inflate rates during early periods of widespread detection artificially. In contrast, evidence indicates that large increases in incidence associated with PSA screening are often accompanied by minimal, delayed, or heterogeneous changes in mortality, reinforcing the notion that screening disproportionately affects incidence rather than mortality [30].

In the current study, the increase in mortality was more significant among men aged 75 and older. Age affects the incidence and mortality of prostate cancer, with mortality rising after age 50 [31]. This pattern may reflect population aging and other health factors, such as related comorbidities and behavioral aspects, including alcohol and tobacco use. These factors have been associated with higher incidence [32,33]. Therefore, promoting healthy lifestyle choices may represent an important complementary strategy, including reducing substance use, is crucial for decreasing mortality [34].

In Sergipe, the mortality-to-incidence ratio (MIR) increased during the study period. This is similar to a Brazilian study, which reported little variation in prostate cancer mortality in Sergipe from 1990 to 2019, with rates ranging from 245.49/100,000–236.88/100,000 [35]. A decrease in PSA-based screening among older adults [36] may partly explain the rise in the MIR. Population growth and shifts in age demographics could also contribute to this pattern [37]. Additionally, the lack of specific strategies for monitoring older populations with advanced disease might have played a role, underscoring the need for public policies to improve access to and the quality of oncological care in Sergipe. The stability observed in prostate cancer mortality trends in the urban area, particularly in the state capital, may reflect a more advanced stage of socioeconomic and health system development, with earlier consolidation of access to healthcare services, disease management, and demographic stabilization. In contrast, the increases observed in inland health regions may be partly influenced by demographic transitions, including population aging and changes in age structure over time, rather than exclusively reflecting deficiencies in cancer control strategies. Therefore, regional differences in mortality trends may primarily represent demographic shifts and heterogeneous stages of epidemiological transition and should not be interpreted as direct evidence of insufficient screening coverage or delayed diagnosis.

Therefore, regional differences in mortality trends should be interpreted with caution, as they may represent a combined effect of demographic shifts, differential stages of epidemiological transition, and heterogeneity in healthcare access. Within this context, although improvements in screening and early diagnosis remain important public health goals, the findings of this ecological study primarily highlight potential structural and demographic inequalities across health regions, rather than providing direct evidence of the effectiveness or impact of screening policies on mortality outcomes.

This study observed a decrease in MIR among individuals aged 15–54 years during the analyzed period. The literature clearly shows that prostate cancer incidence and mortality rise with age, with the average age at diagnosis being 66 years [38]. The younger a person is, the lower the risk of developing the disease. However, the increase in detected cases due to more accessible diagnostic tests and treatment options may also help explain the reduction in the MIR [39]. Additionally, health education programs might have encouraged younger individuals to seek preventive care more often, leading to earlier diagnoses and lower mortality.

This study highlights several notable strengths. It uses population-based data from a reputable cancer registry, performs thorough temporal trend analyses with the Joinpoint Regression Program, and includes the mortality-to-incidence ratio (MIR) as a proxy for survival. Although MIR is a useful indicator when follow-up data is limited, it remains an approximation of survival and can be influenced by competing causes of death, registry quality, and disparities in healthcare access. In addition, MIR-based estimates may be affected by the time lag between cancer incidence and subsequent mortality, particularly for neoplasms with long survival such as prostate cancer, as well as by temporal variations in data completeness and quality across incidence and mortality information systems.

Furthermore, despite the ongoing expansion of the Aracaju Cancer Registry toward statewide coverage, ensuring data completeness and accuracy remains challenging, especially in remote and rural areas of Sergipe. The Joinpoint temporal trend analysis, though effective, may not fully detect subtle non-linear changes and is influenced by the number of observations in the time series. Additionally, even though the model adjusts for first-order autocorrelation, the impact of this correction on the final estimates is not quantified. Nevertheless, the Joinpoint method is still widely recognized for its ability to identify significant inflection points in trend data. It is important to recognize that data quality during the COVID-19 pandemic (2020–2022) may have been

Table 3
Annual Percent Change (APC) and 95 % confidence intervals (95 %CI) for age-adjusted prostate cancer incidence per 100,000 inhabitants and for the age groups 15–54, 55–64, 65–74, and 75 years and over in the health regions of Sergipe, Brazil, 1996–2017.

	ASR			**15–54**			**55–64**			**65–74**			**75 +**		
Region	**JP**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**	**JP Seg**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**
Sergipe	1996–1999	28.70*	(11.92; 66.67)	1996–2008	15.51*	(12.38; 21.96)	1996–1999	61.50*	(21.55; 201.90)	1996–2006	12.24*	(9.08; 18.66)	1996–2006	10.76*	(7.27; 19.18)
	1999–2007	9.93	(-4.68; 12.73)	2008–2017	-3.48*	(-7.00; −0.70)	1999–2008	10.91*	(5.28; 15.09)	2006–2017)	-1.32	(-3.49; 0.50)	2006–2017	-2.1	(-5.77; 0.26)
	2007–2017	-1.66	(-4.34; 1.39)				2008–2017	-1.97	(-5.15; 0.25)						
Capital	1996–1999	31.83*	(23.27; 46.41)	1996–2008	15.48*	(12.75; 19.91)	1996–1999	63.15*	(41.85; 105.59)	1996–1999	25.77*	(11.36; 46.84)	1996–2006	10.90*	(7.71; 17.45)
	1999–2002	1.57	(-4.00; 11.12)	2008–2017	-3.65*	(-7.63; −0.79)	1999–2008	10.99*	(7.87; 15.04)	1999–2007	8.95	(-7.81; 12.71)	2006–2017	-2.19	(-6.50; 0.32)
	2002–2006	16.4	(-3.54; 24.25)				2008–2017	-2.00*	(-4.73; −0.11)	2007–2017	-1.7	(-7.36; 5.11)			
	2006–2017	-1.47	(-2.97; 1.08)												
Aracaju	1996–1999	35.39*	(24.99; 60.35)	1996–2008	15.38*	(12.14; 21.40)	1996–1999	61.20*	(25.73; 191.67)	1996–2006	11.96*	(8.70; 19.15)	1996–2006	10.83*	(7.37; 18.39)
	1999–2002	1.19	(-4.48; 10.91)	2008–2017	-3.59*	(-7.49; −0.73)	1999–2008	11.02*	(6.88. 14.82)	2006–2017	-1.37	(-3.87; 0.60)	2006–2017	-2.17	(-6.40; 0.35)
	2002–2006	16.48	(-3.44; 24.57)				2008–2017	-1.98*	(-4.97; 0.07)						
	2006–2017	-1.47	(-2.81; 0.87)												
Estância	1996–2006	13.41*	(10.52; 19.24)	-			-			1996–2006	13.14*	(10.08; 19.12)	1996–2006	11.45*	(8.03; 19.44)
	2006–2017	-1.28	(-2.92; 0.21)	-			-			2006–2017	-1.33	(-2.90; 0.11)	2006–2017	-2.22*	(-5.04; −0.24)
Glória	1996–2006	14.03*	(11.18; 18.65)	-			-			1996–2006	13.30*	(9.74; 19.35)	1996–2005	12.98*	(9.00; 23.31)
	2006–2017	-1.26	(-2.74; 0.21)	-			-			2006–2017	-1.17	(-3.31; 0.67)	2005–2017	-1.49	(-3.67; 0.32)
Itabaiana	1996–1999	28.34*	(11.54; 67.61)	-			1996–1999	62.12*	(21.37; 188.47)	1996–2006	12.35*	(9.25; 18.42)	1996–2006	10.28*	(7.29; 17.12)
	1999–2007	9.76	(-4.99; 12.96)	-			1999–2008	10.73*	(3.56; 15.56)	2006–2017	-1.42	(-3.28; 0.33)	2006–2017	-2.03*	(-4.76; −0.01)
	2007–2017	-1.63	(-5.15; 2.05)	-			2008–2017	-1.88	(-4.91; 0.22)						
Lagarto	1996–2006	13.27*	(10.17; 19.07)	-			-			1996–2006	12.17*	(8.90; 18.62)	1996–2006	11.03*	(7.21; 20.29)
	2006–2017	-1.28	(-2.95; 0.25)	-			-			2006–2017	-1.2	(-3.30; 0.49)	2006–2017	-2.16*	(-4.60; −0.17)
Propriá	1996–2006	13.38*	(10.45; 18.48)	-			-			1996–2006	13.07*	(10.04; 19.09)	1996–2005	11.88*	(7.23; 25.24)
	2006–2017	-1.32	(-3.1; 0.36)				-			2006–2017	-1.47	(-3.66; 0.43)	2005–2017	-1.59	(-4.14; 0.24)
Socorro	1996–2007	11.16*	(8.92; 15.16)	-			-			1996–2006	11.98*	(8.62; 19.07)	1996–2005	11.89*	(7.35; 24.08)
	2007–2017	-1.85*	(-3.59; −0.26)	-			-			2006–2017	-1.12	(-3.33; 0.80)	2005; 2017	-1.26	(-4.09; 0.64)

Note: JP: Joinpoint segment; ASR: Age Standard Rate; * p < 0,05

Table 4
Annual Percent Change (APC) and 95 % confidence intervals (95 %CI) for age-adjusted prostate cancer mortality per 100,000 inhabitants and for the age groups 15–54, 55–64, 65–74, and 75 years and over in the health regions of Sergipe, Brazil, 1980–2022.

Region	ASR			15–54			55–64			65–74			75 +		
	JP	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**	**JP**	**APC**	**(95 %CI)**
Sergipe	1980–2001	4.82	(-0.11; 6.28)	1982–2022	0	(-1.77; 1.83)	1980–2022	3.45*	(2.09; 4.85)	1980–2009	6.60*	(4.71; 51.44)	1980–1997	2.33	(-4.61; 5.11)
	2001–2005	22.15*	(7.26; 37.95)							2009–2022	-1.65	(-45.05; 4.19)	1997–2006	18.06*	(10.48; 53.81)
													2006–2022	-0.01	(-4.01; 2.74)
Capital	1980–2006	2.13*	(0.89; 19.32)	1982–2021	-2.37*	(-4.51; −0.17)	1980–2022	-1.01	(-2.84; 0.85)	1980–2022	-0.37	(-1.62; 0.88)	1980–2022	1.74*	(0.59; 2.89)
	2006–2022	-1.97	(-22.93; 0.51)												
Aracaju	1980–2006	2.84*	(1.71; 17.25)	1982–2021	-2.08	(-4.29; 0.30)	1980–2022	0.1	(-1.53; 1.80)	1980–2022	0.65	(-0.48; 1.79)	1980–1990	-6.1	(-30.59; 4.12)
	2006–2022	-0.87	(-20.26; 1.38)										1990–1994	27.01	(-12.09; 57.52)
													1994–2022	1.09	(-3.26; 5.53)
Estância	1983–2022	7.20*	(5.27; 9.18)	2006–2020	-3.84	(-7.93; 0.52)	1988–2022	0.29	(-1.86; 3.00)	1990–2022	2.52	(-0.40; 5.63)	1983–2001	-2.77	(-10.80; 1.48)
													2001–2004	92.44*	(26.24; 130.54)
													2004–2022	0.64	(-4.58; 4.00)
Glória	1984–1995	3.91	(-3.74; 15.57)	-			2005–2021	-0.38	(-7.77; 7.19)	1984–2022	0.15	(-2.03; 2.59)	1994–2022	7.68*	(4.02; 11.67)
	1995–2001	-20.69	(-44.50; 54.95)												
	2001–2004	111.14*	(5.22; 156.14)												
	2004–2022	2.93	(-0.48; 5.93)												
Itabaiana	1980–2001	-3.03	(-8.13; 0.78)	1984–2022	-3.20*	(-4.74; −1.83)	1984–2017	-0.99	(-2.87; 6.86)	1990–2003	14.66*	(3.31; 54.83)	1980–2001	-5.21*	(-10.48; −1.08)
	2001–2004	112.48*	(31.92; 153.11)				2017–2022	-16.50*	(-61.86; −3.17)	2003–2022	-3.57	(-37.57; 0.73)	2001–2004	115.35*	(38.79; 157.37)
	2004–2022	-2.29	(-6.86; 1.17)										2004–2022	-0.66	(-5.04; 2.47)
Lagarto	1980–1999	0.38	(-5.80; 4.94)	-			1987–2022	-1.54	(-5.93; 3.64)	1985–2022	4.14*	(1.42; 7.13)	1980–1998	-2.39	(-10.24; 3.41)
	1999–2005	48.33*	(26.76; 118.17)										1998–2007	32.24*	(19.68; 103.47)
	2005–2022	-1.03	(-5.60; 2.75)										2007–2022	-1.22	(-6.43; 2.70)
Propriá	1980–2009	9.74*	(7.09; 23.47)	1984–2022	-3.20*	(-4.74; −1.83)	1980–2022	-1.42	(-3.36; 0.95)	1989–2022	0.85	(-1.51; 3.38)	1983–2017	7.04*	(5.24; 10.29)
	2009–2022	-1.83	(-32.61; 4.91)										2017–2022	-21.39*	(-58.00; −0.94)
Socorro	1980–1985	-39.47*	(-50.99; −4.45)	1993–2022	-2.12	(-6.20; 2.58)	1980–1990	-15.06*	(-22.36; −1.59)	1980–2022	-3.07	(-5.97; 0.66)	1980–2022	-6.19*	(-9.40; −2.06)
	1985–2022	2.92*	(0.60; 7.32)				1990–2022	-0.58	(-29.38; 27.09)						

Note: JP: Joinpoint segment; ASR: Age Standard Rate; * $p < 0,05$

Table 5
Mortality-to-incidence ratio (MIR), 95 % confidence intervals (95 %CI), and probability of survival (PS) for prostate cancer in the health regions and in the state of Sergipe, 1996–2017.

Region	15–54		55–64		65–74		75 +		ASR	
	MIR (95 %CI)	SP (%)	MIR (95 %CI)	SP (%)	MIR (95 %CI)	SP (%)	MIR (95 %CI)	SP (%)	MIR (95 %CI)	SP (%)
Sergipe										
1996–1999	0.30 (-0.27; 0.88)	69.67	0.19 (0.09; 0.28)	81.39	0.21 (0.16; 0.26)	79.35	0.29 (0.25; 0.33)	70.90	0.23 (0.08; 0.39)	76.57
2000–2004	0.13 (-0.16; 0.41)	87.45	0.14 (0.08; 0.19)	86.28	0.19 (0.15; 0.23)	81.05	0.38 (0.35; 0.42)	61.81	0.23 (0.11; 0.34)	77.35
2005–2009	0.07 (-0.09; 0.23)	93.08	0.12 (0.08; 0.16)	87.91	0.18 (0.15; 0.21)	81.96	0.53 (0.50; 0.56)	47.18	0.25 (0.15; 0.34)	75.24
2010–2014	0.07 (-0.08; 0.23)	92.51	0.10 (0.06; 0.13)	90.25	0.18 (0.15; 0.21)	81.66	0.54 (0.51; 0.58)	45.55	0.25 (0.15; 0.34)	75.48
2015–2017	0.12 (-0.10; 0.34)	87.76	0.11 (0.07; 0.15)	89.49	0.20 (0.17; 0.23)	79.80	0.68 (0.65; 0.71)	31.67	0.29 (0.18; 0.39)	71.27
Capital										
1996–1999	0.83 (0.36; 1.30)	17.01	0.47 (0.34; 0.59)	53.49	0.53 (0.47; 0.60)	46.54	-	-	0.76 (0.61; 0.92)	23.63
2000–2004	0.35 (-0.06; 0.75)	65.46	0.24 (0.17; 0.31)	76.01	0.36 (0.32; 0.41)	63.90	0.97 (0.96; 0.99)	2.56	0.50 (0.36; 0.64)	49.85
2005–2009	0.09 (-0.09; 0.28)	90.70	0.16 (0.12; 0.21)	83.87	0.23 (0.20; 0.26)	77.00	0.68 (0.65; 0.71)	32.34	0.32 (0.21; 0.42)	68.42
2010–2014	0.12 (-0.07; 0.32)	87.85	0.08 (0.05; 0.12)	91.77	0.22 (0.19; 0.25)	78.06	0.73 (0.70; 0.76)	27.21	0.31 (0.20; 0.41)	69.42
2015–2017	0.18 (-0.07; 0.44)	81.59	0.10 (0.06; 0.14)	89.71	0.23 (0.20; 0.27)	76.81	0.81 (0.79; 0.84)	18.54	0.34 (0.22; 0.45)	66.29
Aracaju										
1996–1999	0.66 (0.08; 1.25)	33.64	0.43 (0.31; 0.56)	56.63	0.42 (0.36; 0.49)	57.53	0.96 (0.95; 0.98)	3.51	0.61 (0.43; 0.79)	38.62
2000–2004	0.27 (-0.11; 0.66)	72.57	0.23 (0.16; 0.30)	76.85	0.31 (0.27; 0.35)	69.07	0.80 (0.77; 0.83)	19.77	0.42 (0.28; 0.56)	57.56
2005–2009	0.10 (-0.09; 0.29)	89.83	0.14 (0.09; 0.18)	86.49	0.20 (0.17; 0.23)	79.93	0.61 (0.58; 0.64)	38.76	0.28 (0.18; 0.38)	71.75
2010–2014	0.11 (-0.08; 0.29)	89.26	0.09 (0.05; 0.13)	91.00	0.22 (0.19; 0.25)	77.75	0.65 (0.62; 0.68)	35.02	0.29 (0.19; 0.39)	71.05
2015–2017	0.19 (-0.07; 0.45)	81.15	0.11 (0.07; 0.15)	89.44	0.21 (0.18; 0.25)	78.54	0.81 (0.78; 0.84)	19.01	0.33 (0.22; 0.44)	67.18
Estância										
1996–1999	0.00 (0.00; 0.00)	100.00	0.00 (0.00; 0.00)	100.00	0.16 (0.12; 0.21)	83.66	0.13 (0.10; 0.16)	86.94	0.13 (0.00; 0.25)	87.39
2000–2004	0.00 (0.00; 0.00)	100.00	0.05 (0.01; 0.09)	95.02	0.06 (0.04; 0.08)	93.90	0.29 (0.26; 0.32)	71.03	0.12 (0.03; 0.21)	87.86
2005–2009	0.05 (-0.09; 0.19)	94.81	0.06 (0.03; 0.09)	93.59	0.16 (0.13; 0.19)	84.23	0.49 (0.46; 0.52)	50.61	0.22 (0.13; 0.31)	78.12
2010–2014	0.04 (-0.08; 0.16)	95.91	0.10 (0.06; 0.14)	89.70	0.21 (0.18; 0.25)	78.55	0.43 (0.40; 0.47)	56.60	0.23 (0.14; 0.33)	76.91
2015–2017	0.04 (-0.09; 0.17)	95.81	0.14 (0.09; 0.18)	86.03	0.19 (0.16; 0.22)	80.85	0.56 (0.53; 0.60)	43.71	0.26 (0.15; 0.36)	74.23
Glória										
1996–1999	0.50 (-0.12; 1.12)	49.85	0.00 (0.00; 0.00)	100.00	0.06 (0.03; 0.09)	94.19	0.04 (0.02; 0.06)	96.20	0.07 (-0.03; 0.16)	93.45
2000–2004	0.00 (0.00; 0.00)	100.00	0.00 (0.00; 0.00)	100.00	0.11 (0.08; 0.14)	89.39	0.12 (0.10; 0.15)	87.55	0.07 (0.00; 0.15)	92.60
2005–2009	0.00 (0.00; 0.00)	100.00	0.14 (0.10; 0.18)	85.93	0.09 (0.07; 0.11)	90.90	0.33 (0.30; 0.36)	66.74	0.16 (0.08; 0.24)	83.97
2010–2014	0.00 (0.00; 0.00)	100.00	0.03 (0.01; 0.06)	96.55	0.12 (0.10; 0.15)	87.88	0.47 (0.44; 0.51)	52.61	0.18 (0.09; 0.27)	81.98
2015–2017	0.00 (0.00; 0.00)	100.00	0.12 (0.07; 0.16)	88.35	0.18 (0.15; 0.21)	82.10	0.44 (0.40; 0.47)	56.43	0.21 (0.11; 0.31)	78.97
Itabaiana										
1996–1999	0.00 (0.00; 0.00)	100.00	0.10 (0.03; 0.17)	90.09	0.12 (0.08; 0.16)	87.93	0.08 (0.06; 0.11)	91.52	0.10 (-0.01; 0.20)	90.47
2000–2004	0.12 (-0.16; 0.39)	88.33	0.05 (0.02; 0.09)	94.58	0.21 (0.18; 0.25)	78.52	0.24 (0.21; 0.27)	76.19	0.18 (0.07; 0.28)	82.39
2005–2009	0.11 (-0.09; 0.30)	89.37	0.02 (0.01; 0.04)	97.54	0.15 (0.13; 0.18)	84.61	0.49 (0.46; 0.52)	51.30	0.20 (0.11; 0.29)	79.84
2010–2014	0.08 (-0.08; 0.23)	92.44	0.07 (0.04; 0.11)	92.74	0.11 (0.08; 0.13)	89.27	0.51 (0.48; 0.55)	48.60	0.20 (0.11; 0.29)	80.12
2015–2017	0.38 (0.06; 0.70)	61.79	0.11 (0.07; 0.15)	89.23	0.23 (0.19; 0.26)	77.43	0.60 (0.56; 0.63)	40.32	0.29 (0.18; 0.40)	70.75
Lagarto										
1996–1999	0.32 (-0.26; 0.90)	67.91	0.00 (0.00; 0.00)	100.00	0.06 (0.03; 0.09)	93.83	0.04 (0.02; 0.06)	95.80	0.05 (-0.03; 0.13)	94.99
2000–2004	0.10 (-0.16; 0.35)	90.38	0.11 (0.06; 0.17)	88.68	0.11 (0.08; 0.14)	88.56	0.20 (0.17; 0.23)	80.16	0.14 (0.04; 0.24)	86.15
2005–2009	0.02 (-0.07; 0.11)	97.95	0.15 (0.11; 0.20)	84.70	0.18 (0.15; 0.21)	82.24	0.56 (0.53; 0.59)	43.85	0.26 (0.16; 0.36)	73.85
2010–2014	0.03 (-0.07; 0.14)	96.70	0.10 (0.06; 0.14)	89.93	0.13 (0.11; 0.16)	86.52	0.58 (0.55; 0.61)	42.23	0.23 (0.14; 0.33)	76.88
2015–2017	0.00 (0.00; 0.00)	100.00	0.06 (0.03; 0.09)	94.34	0.16 (0.13; 0.19)	83.80	0.76 (0.73; 0.78)	24.42	0.27 (0.16; 0.38)	72.94
Propriá										
1996–1999	0.00 (0.00; 0.00)	100.00	0.00 (0.00; 0.00)	100.00	0.09 (0.06; 0.13)	90.80	0.14 (0.11; 0.17)	85.98	0.09 (-0.02; 0.19)	91.14
2000–2004	0.00 (0.00; 0.00)	100.00	0.20 (0.13; 0.26)	80.40	0.15 (0.11; 0.18)	85.19	0.24 (0.21; 0.27)	75.70	0.18 (0.07; 0.29)	81.99
2005–2009	0.09 (-0.09; 0.27)	91.08	0.14 (0.10; 0.19)	85.81	0.20 (0.17; 0.23)	80.30	0.47 (0.43; 0.50)	53.46	0.25 (0.15; 0.34)	75.30
2010–2014	0.12 (-0.07; 0.31)	88.14	0.08 (0.05; 0.12)	91.63	0.18 (0.15; 0.21)	82.37	0.48 (0.45; 0.51)	51.71	0.23 (0.13; 0.32)	77.40
2015–2017	0.08 (-0.10; 0.25)	92.42	0.09 (0.05; 0.13)	90.76	0.21 (0.18; 0.24)	79.01	0.63 (0.60; 0.66)	37.00	0.26 (0.16; 0.37)	73.69
Socorro										
1996–1999	0.65 (0.06; 1.25)	34.62	0.10 (0.03; 0.18)	89.53	0.08 (0.05; 0.12)	91.61	0.00 (0.00; 0.00)	100.00	0.08 (-0.02; 0.18)	91.98
2000–2004	0.98 (0.87; 1.09)	1.70	0.10 (0.05; 0.15)	90.28	0.00 (0.00; 0.00)	100.00	0.08 (0.06; 0.10)	91.71	0.09 (0.01; 0.17)	90.83
2005–2009	0.24 (-0.03; 0.51)	76.24	0.17 (0.12; 0.22)	82.84	0.07 (0.05; 0.09)	93.19	0.06 (0.05; 0.08)	93.86	0.10 (0.04; 0.17)	89.60
2010–2014	0.35 (0.06; 0.63)	65.41	0.11 (0.07; 0.15)	89.11	0.07 (0.05; 0.09)	93.11	0.04 (0.02; 0.05)	96.49	0.09 (0.02; 0.15)	91.14
2015–2017	0.53 (0.19; 0.86)	47.42	0.15 (0.10; 0.19)	85.47	0.07 (0.05; 0.09)	93.01	0.05 (0.03; 0.06)	95.46	0.11 (0.03; 0.18)	89.32

compromised, potentially leading to an underestimation of the true disease burden during that period. Finally, the findings of this study should be interpreted considering its ecological design. As such, the analyses do not allow causal inference at the individual level, and observed associations between incidence, mortality, and regional characteristics cannot be directly attributed to specific exposures, healthcare practices, or policy interventions.

5. Conclusion

This study examined prostate cancer incidence, mortality, and survival in Sergipe from 1980 to 2022, revealing regional and temporal differences. Incidence rates increased starting in 1996, with notable rises in Aracaju, Itabaiana, Lagarto, and Propriá, while Nossa Senhora do Socorro and the 15–54-year age group in the capital experienced decreases during certain periods. Age-adjusted mortality rose across the state, especially among older adults, with significant variations in Nossa Senhora da Glória, Propriá, Lagarto, and Itabaiana. In Aracaju, mortality increased until 2000, then declined, particularly among younger individuals. These results emphasize regional disparities in disease progression and access to healthcare services.

The Mortality-to-Incidence Ratio (MIR) showed regional differences, indicating a decline in survival in some areas. Initially, the capital had the highest MIR, reflecting lower survival rates among younger individuals. Over time, the MIR increased among older adults, while it decreased among those aged 15–54 years, especially in the capital. However, overall survival in the state worsened, except for older adults, who faced more adverse outcomes. In Propriá, the MIR rose across all age groups. These findings highlight the need for targeted strategies to address regional and age-related disparities.

CRediT authorship contribution statement

Ana Clara Cruz Santos de Santana: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Brenda Evelin Barreto da Silva:** Writing – original draft, Formal analysis, Data curation. **Ellen Sabrina Ramos Santos:** Writing – original draft, Data curation. **Jefferson Felipe Calazans Batista:** Writing – original draft, Formal analysis, Data curation. **Alex Rodrigues Moura:** Writing – review & editing, Formal analysis. **Carlos Anselmo Lima:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors report no competing interests associated with this research.

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