THE EVIDENCE

www.evidencejournals.com

Research Article | Public Health

Check for updates

Cancer burden and trends across India (1990-2021): insights from the Global Burden of Disease study

Diptismita Jena[1], Prafulla Kumar Swain[2*], Nandhni Chiruganam Gandhi[3], Visweswara Rao Guthi[4], Aarthy Ramasamy[5], Sree Sudha TY[6], Priyadharshini. P[7], Sai Sree Valli Sreepada[8], Carlos Quispevicuna[9], Mirza Adil Beig[10], DM Shilpa[11], Arathi P Rao[12]

[1] Department of Statistics, Ravenshaw University, Cuttack, India.
[2] Department of Statistics, Utkal University, Bhubaneswar, India.
[3] Centre for Population Health Sciences, The University of Edinburgh, Edinburgh, United Kingdom.
[4] Department of Community Medicine, SVIMS-Sri Padmavathi Medical College for Women, Tirupati, India.
[5] NCD Division, ICMR-National Institute of Epidemiology, Chennai, India.
[6] Department of Pharmacology, All India Institute of Medical Sciences, Deoghar, India.
[7] Department of Community Medicine, Sri Lalithambigai Medical College and Hospital, Chennai, Tamilnadu, India.
[8] Department of Community Medicine School of Public Health, Postgraduate Institute of Medical Education and Research, Chandigarh, India.
[9] Red De Eficacia Clinica Y Sanitaria REDECS, Lima, Peru.
[10] Department of Population Health Informatics, Dehradun Institute of Technology, Dehradun, India.
[11] School of Public Health, JSS Academy of Higher Education and Research, Mysore, India.
[12] Prasanna School of Public Health, Manipal Academy of Higher Education, Manipal, India.

Correspondence: prafulla86@gmail.com

evidence Journals

Cite this Article

Jena D, Swain PK, Gandhi NC, Guthi VR, Ramasamy A, TY SS, P P, Valli Sreepada SS, Quispevicuna C, Beig MA, Shilpa D, Rao AP, Cancer burden and trends across India (1990-2021): insights from the Global Burden of Disease study. The Evi. 2024:2(3):1-. DOI:10.61505/evidence.2024.2.3.82
Available From
https://the.evidencejournals.com/index.php/j/article/view/81

Received:	2024-06-27
Accepted:	2024-07-01
Published:	2024-07-03

Evidence in Context

• Cancer incidence increased by 34.94% and mortality by 46.02% (1990-2021). • Significant jumps in incidence and prevalence occurred between 2006-2009. • DALY rates initially declined until 2004, then varied. • Highest cancer rates found in southern and northeastern states. • Emphasizes targeted prevention and early detection, especially for the elderly.

To view Article

Abstract

Background: This study investigates the rising burden of cancer in India between 1990 and 2021. The age-standardized mortality rate (ASMR) grew by 46.02%, reaching 60.44 per 100,000 population in 2021 compared to 41.39 in 1990. The incidence rate also exhibited a significant increase of 34.94% during this period. We utilized data from the Global Burden of Disease (GBD) to comprehensively analyze trends in four key cancer metrics: incidence, prevalence, disability-adjusted life years (DALYs), and ASMR.

Methods: Joinpoint regression analysis was employed to reveal temporal trends in these metrics. This method estimates the Annual Percent Change (APC) and Average Annual Percent Change (AAPC) at potential joinpoints (significant shifts in trend).

Results: A concerning upward shift in cancer incidence, prevalence, DALYs, and ASMR was identified using joinpoint analysis. Notably, both prevalence and incidence rates exhibited a significant jump around 2006-2009, followed by a period of moderation. The DALY rate initially declined until 2004, likely reflecting improvements in healthcare. However, this trend subsequently became more variable. The ASMR displayed a U-shaped trajectory, initially decreasing, then increasing, and finally exhibiting a slight recent decline.

Conclusion: Our findings demonstrate a substantial increase in India's cancer burden. To mitigate this challenge, effective policy programs should prioritize both preventive measures and early detection strategies, with a particular focus on the vulnerable elderly population. Such interventions have the potential to reduce new cancer cases, improve the quality of life for cancer patients, and potentially decrease cancer-related mortality.

Keywords: *cancer, GBD, prevalence, incidence, DALYs, age standardise mortality rate.*

Introduction

Cancer continues to stand as a prominent issue in the realm of public health, exerting a considerable impact on mortality and morbidity rates worldwide [1]. Internationally, cancer is identified as one of the top two contributors to mortality in over half of the total number of countries, which amounts to 91 out of 172 nations. Furthermore, in 22 other countries, it is positioned as the third or fourth most prominent factor leading to death [2]. Comprehensive data from the Global Burden of Disease (GBD) studies have been pivotal in illustrating the evolving landscape of cancer, marking an increase in incidence and mortality rates across numerous regions (Global Burden of Disease Cancer Collaboration, 2021). This upward trend is attributable to several factors, including demographic changes with an aging population, increased exposure to known risk factors, and possibly improvements in diagnostic capabilities. Furthermore, lifestyle changes across the globe, such as increased prevalence of smoking, poor diet, and physical inactivity, contribute significantly to the cancer burden. Population growth and ageing populations are one explanation for the rise in cancer burden, but other factors like lifestyle changes may also play a role [3, 4]. These shifts necessitate robust public health responses, encompassing prevention, early detection, effective treatment, and palliative care [5]. International collaborations and the integration of innovative technologies in cancer care are also crucial. Cancer is becoming more of a problem in low- and middle-income. Low- and middle-income nations currently carry the predominant portion of the cancer burden, yet their healthcare infrastructures are notably unequipped to confront this issue [6].

In India, the cancer burden reflects significant epidemiological and demographic diversity across its states. The substantial variations in development levels influenced by variations in risk factor exposures, healthcare access, and economic disparities population genetics, environmental exposures and lifestyle choices across these regions contribute to a heterogeneous landscape of disease burden and health outcomes [7]. Prior research has explored the national picture of cancer burden and its variations across India. These studies have also identified key areas for improving cancer control efforts in the country [1,8,9]. Data paints a concerning picture, with millions succumbing to this disease annually. The mortality rate in 1990 was 41.39 per 100,000 population and 60.44 per 100,000 in 2021. This represents a 46.02% increase in three decades. The incidence rate of cancer increased by 34.94% between 1990 and 2021. In India, breast cancer stands out as the most frequent cause of both new cancer diagnoses and cancer deaths among women. It was responsible for over 13.5% of all new female cancers and 10% of cancer deaths in women in 2020 [10]. According to the GBD report 2021, a significant shift has occurred in the leading cause of cancer deaths in India. Breast cancer has overtaken stomach cancer, which was the leading cause of cancer deaths in 1990. This highlights the changing landscape of cancer burden in the country

The sharp rise in cancer incidence in India has placed a significant strain on public healthcare resources, leading to capacity issues and overcrowding in cancer treatment facilities. This overwhelming burden has resulted in characterizations of India's cancer situation as an epidemic or a tsunami [11-13]. Fighting cancer is a global priority, with the United Nations Sustainable Development Goal (SDG) aiming to reduce cancer deaths by a third by 2030. India initiated its National Cancer Registry Programme (NCRP) in 1982. Since then, the program has steadily grown, incorporating population-based cancer registries (PBCRs) in various urban centres and expanding to include some rural areas. Effective cancer control in India requires a multipronged approach that includes enhancing healthcare infrastructure, promoting education and awareness about cancer prevention, and implementing state-specific cancer control programs [7].

This comprehensive analysis will investigate the evolving cancer burden in India across three decades (1990-2021). We will leverage the GBD framework to analyse trends in prevalence, incidence, mortality, and disability-adjusted life years (DALYs). The study will not only examine the leading cancer types affecting the Indian population and identify potential reasons for the rising burden, but it will also employ spatial analysis to explore geographic variations in these metrics across India. This will allow us to identify regions experiencing significant changes in cancer burden over the past 30 years. By combining trend analysis with a spatial dimension, this study aims to provide a more nuanced understanding of the public health challenge posed by cancer in India. This knowledge can inform targeted interventions and resource allocation to mitigate the growing cancer burden and improve health outcomes across the country.

Data Sources and Methodology

This study delves into the landscape of cancer in India, utilizing data from the GBD India Compare 2021 (https://vizhub.healthdata.org/gbd-compare/india) [14]. This comprehensive resource, a collaborative effort by the Institute for Health Metrics and Evaluation (IHME), the Indian Council of Medical Research (ICMR), and the Public Health Foundation of India (PHFI), offers a wealth of information on various health aspects, including causes of disease. The GBD India Compare employs a hierarchical structure for categorizing disease causes. Cancer or neoplasms, occupies level three, encompassing all cancer types. Further granularity is offered at level four, where data on specific cancers like breast and stomach cancer can be found. To gain a holistic understanding of the cancer burden in India, this study extracts data from level three, encompassing the period from 1990 to 2021.

While the GBD India Compare provides data for various age groups, this study adopts a broader approach. It analyses data across all age groups to estimate the overall cancer burden impacting the entire Indian population. To further assess this burden, the study extracts data on four key metrics: cancer prevalence (the number of existing cases) and disability-adjusted life years (DALYs) associated with cancer incidence and crude mortality rate. This combined analysis provides a more comprehensive picture of the societal impact of cancer in India.

Methods

This study employs a comprehensive statistical approach to analyse cancer burden trends in India from 1990 to 2021. Descriptive statistics are initially presented to summarize the overall distribution of each cancer metric.

Joinpoint regression analysis, performed using the Joinpoint Regression Program version 5.0 (National Cancer Institute), is the core component of the trend analysis. This method allows for the identification of potential inflection points (joinpoints) in the time series data for each cancer metric. The analysis selects the best-fitting model based on statistical criteria. This model provides estimates of the Annual Percentage Change (APC) for each identified trend segment. Additionally, the Average Annual Percentage Change (AAPC) summarizes the overall trend across the entire study period. If no significant joinpoints are detected, a single APC value represents the trend for the entire timeframe. The detailed mathematical framework underlying joinpoint regression analysis is presented in a separate section for those seeking a more in-depth understanding of the statistical methodology. This section explores how joinpoint regression is used to analyse trends in cancer metrics like DALY, incidence, prevalence and crude mortality rate.

Prevalence denotes the aggregate amount of current cancer instances among a population at a particular point in time. It is also expressed as a rate per 100,000 individuals. Incidence pertains to the number of new cancer occurrences identified within a designated population and time period. It is typically expressed as a rate per 100,000 individuals per year. DALYs serve as a standardized metric encompassing both years of life lost due to premature mortality (Years of Life Lost (YLL)) and years of healthy life lost due to disability (Years Lived with Disability (YLD)) [15]. DALYs are measured in years, representing the equivalent of one year of healthy life lost due to illness, disability, or premature death.

$$DALY=YLD+YLL \quad (1)$$

The formulas for YLL and YLD provide the framework for calculating DALYs [15].

$$YLD=Px*DW*Lx \quad (2)$$

Where, Px is the number of prevalent cases within a specific age group (x), DW Disability Weight (A value ranging from 0 (perfect health) to 1 (death), reflecting the severity of disability associated with the condition and Lx average duration of illness. The average length of time an individual experiences the illness within a specific age group, measured in years.

$$YLL=dx*ex \quad (3)$$

Where dx represent the number of deaths occurring within different age groups and ex represent the average remaining life expectancy for a specific age group, assuming a standard mortality pattern.

Joinpoint Regression Analysis

This study utilizes joinpoint regression analysis to pinpoint critical periods of change in cancer burden across four key metrics: age standardised mortality rate, DALYs age standardised rate, prevalence age standardised rate, and incidence age standardised rate. The

Analysis spans a comprehensive period from 1990 to 2021, aiming to identify significant shifts in cancer trends across these crucial measures.

The joinpoint regression model is commonly employed in statistical modeling for analyzing observations $\{(x_1,y_1),(x_2,y_2)\ldots\ldots,(x_n,y_n)\}$, where $x_1 \le x_2 \le \cdots\ldots \le x_n$ [16]. The simple linear joinpoint regression model with k+1 segments for i=1,2,….,n , can be written as:

$E(y|x)=\beta_0+\beta_1 x+\delta_1 (x-\tau_i)^+ +\cdots+\delta_k (x-\tau_k)^+ +\varepsilon_i=\beta_0+\beta_1 x+\sum_{i=1}^{k} \delta_1 (x-\tau_i)$ (4)

Where $(x-\tau_k)^+=\{(x-\tau_k),\ x>\tau_k \;@\; 0,\ \text{otherwise}\}$, $\delta_k=\beta_{(k+1)}-\beta_k$ and $\varepsilon_i \approx N(0,\sigma^2)$

The APC and AAPC were introduced with the aim of providing a succinct and comparative analysis of the varying rates of transformation in all dimensions related to cancer that transpire within a specified timeframe [17] and it is given by:

$APC=(e^{(\beta_1+\delta_1+\delta_2+\cdots+\delta_j)})\times 100$ (5) $AAPC=\{\exp(\sum w_i \beta_i/(\sum w_i))-1\}\times 100$ (6)

Results

This analysis delves into cancer burden trends in India across a comprehensive period spanning 1990 to 2021. To gain a foundational understanding of the study population, we begin by examining the descriptive characteristics presented in Table 1. Summarizing the distribution of key cancer burden metrics like incidence rate, prevalence rate, YLL, YLD, DALYs and CDR.

Table 1: Descriptive Characteristics of Cancer Cases of All Ages in India (1990-2021)

Year	Prevalence Rate	Incidence Rate	YLD	YLL	DALYs	Mortality Rate
1990	740	387.7	19.52	1488.86	1508.38	41.39
1991	743.66	389.13	19.72	1494.87	1514.59	41.74
1992	747.59	390.69	19.99	1504.78	1524.77	42.27
1993	749.75	391.53	20.02	1498.1	1518.11	42.26
1994	753.2	393.03	20.26	1504.67	1524.92	42.94
1995	756.1	394.14	20.4	1505.92	1526.33	43.33
1996	759.94	395.47	20.62	1516.43	1537.04	43.7
1997	764.29	397.05	20.91	1530.33	1551.24	44.17
1998	768.5	398.53	21.13	1536.45	1557.58	44.48
1999	771.08	399.01	21.05	1514.22	1535.27	43.65
2000	773.91	400.04	21.09	1501.68	1522.77	43.4
2001	777	401.51	21.19	1495.31	1516.49	43.59
2002	779.74	402.77	21.21	1476.73	1497.94	43.52
2003	782.5	404.16	21.25	1461.19	1482.44	43.63
2004	785.35	405.28	21.21	1444.56	1465.77	43.38
2005	790.92	407.35	21.5	1452.82	1474.31	43.81
2006	813.04	415.47	21.87	1456.99	1478.86	44.26
2007	858.85	432.53	22.46	1475.19	1497.65	45.3
2008	912.64	452.21	23.06	1488.18	1511.24	45.96
2009	958.48	468.63	23.46	1486.05	1509.51	46.02
2010	985.15	478.03	24.21	1511.93	1536.15	47.12
2011	994.75	481.31	24.86	1532.44	1557.3	48.15
2012	1005.99	484.7	25.56	1554.96	1580.52	49.06
2013	1019.44	488.78	26.47	1586.47	1612.94	50.53
2014	1030.74	492.51	27.19	1604.35	1631.53	51.63
2015	1046.2	497.37	28.38	1651.69	1680.07	53.23
2016	1060.64	501.81	29.42	1684.94	1714.36	54.5
2017	1076.63	506.83	30.65	1733.34	1763.99	56.38
2018	1089.87	511.61	31.71	1771.23	1802.94	58.25
2019	1102.38	515.7	32.54	1791.05	1823.59	59.39

2020	1112.63	519.47	33.14	1804.52	1837.66	59.95
2021	1123.35	523.15	33.75	1813.66	1847.41	60.44
Average (x)	888.57	441.48	24.06	1558.56	1582.62	47.54
S.D. (σ)	140.55	49.89	4.44	111.73	115.94	5.94
3σ CL ($x \pm 3\sigma$)	(466.94-1310.21)	(291.80-591.17)	(10.72-37.39)	(1223.36-1893.76)	(1234.81-1930.42)	(29.71-65.38)
Percentage change (1990 to 2021)	51.80%	34.94%	72.94%	21.81%	22.48%	46.02%

A consistent rise in the prevalence rate was observed, escalating from 740.00 per 100,000 individuals in 1990 to 1123.35 per 100,000 individuals in 2021, indicating a 51.80% surge during this timeframe. The frequency of occurrences also demonstrates a positive trajectory, escalating from 387.70 per 100,000 individuals in 1990 to 523.15 per 100,000 individuals in 2021, indicating a surge of 34.94%. The average YLD rate shows a moderate increase from 19.52 years per 100,000 people in 1990 to 33.75 years per 100,000 in 2021 (72.94% increase). The YLL rate has also increased, from 1488.86 per 100,000 in 1990 to 1813.66 per 100,000 in 2021 (21.81% increase). The DALY rate has increased from 1508.38 per 100,000 in 1990 to 1847.41 per 100,000 in 2021, reflecting a 46.02% increase. The mortality rate shows a similar upward trend, increasing from 41.39 per 100,000 in 1990 to 60.44 per 100,000 in 2021 (46.02% increase).

Figure 1 represents three-dimensional plots illustrating the trends in the burden of cancer in India from 1990 to 2021, separated into different metrics: prevalence, incidence, DALYs, and crude mortality rates. Each plot depicts a strong upward trend in different aspect of burden of cancer by age group over time. The trend of prevalence increases with age, reflecting that older age groups tend to have more cases of cancer. The colour gradient from blue to red indicates rising prevalence rates over time, especially noticeable in elder age groups. Like prevalence, the incidence rates increase with age and over time. The colour gradient shows a steady increase, suggesting that more new cases are being diagnosed each year across all age groups. DALYs quantify the comprehensive scope of disease burden by calculating the number of years that are lost as a result of poor health, impairment, or premature mortality. The plot peaks in the middle age groups, indicating that these age groups bear a significant burden of cancer, potentially due to high mortality and disability in these ages. Over time, there appears to be a shift towards higher DALYs rates across all age groups. The mortality trend increases with age, which is typical for cancer mortality. The colour gradient from blue to red indicates an increase in mortality rates over the years, especially pronounced in older age groups. Overall, the graphs highlight an increasing trend in both the incidence and prevalence of cancer, stable but significant DALYs, and rising crude mortality rates influenced by demographic changes rather than increased lethality of cancer.

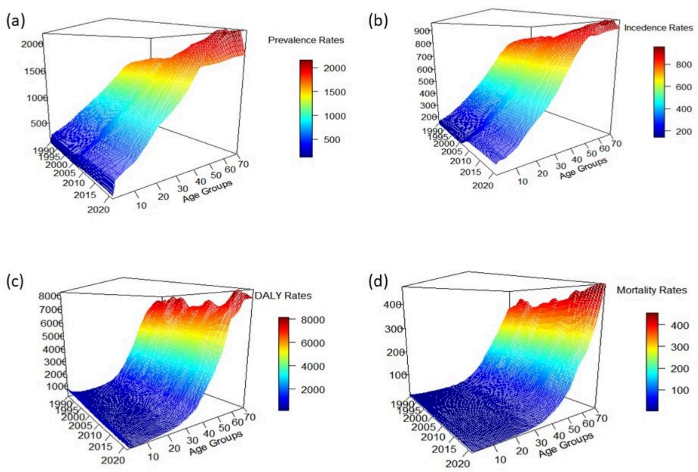

Figure 1: Three-dimensional plots depicting burden of cancer trends in prevalence (a), incidence (b), DALYs (c) and crude mortality rate (d) in India (1990-2021).

Continuing the analysis of cancer burden trends in India (1990-2021), the presented line graphs in Figure 2 depict crucial insights. These graphs compare crude and age-standardized

Rates for prevalence, incidence, DALYs, and mortality. In the case of prevalence both the crude and age-standardized rates show an upward trend, with the age-standardized rate slightly higher, indicating an increase in cancer cases when accounting for population age structure changes. The incidence rates follow a similar pattern to prevalence, with both rates increasing steadily over the years. The DALYs rates, both observed and age-standardized, remain relatively stable across the period, with a slight upward trend. This stability indicates that while the burden of cancer (in terms of life years lost to disability or premature death) is significant, it has not drastically worsened when adjusted for age. Mortality rates show a marked increase in crude rates over time, while the age-standardized rate remains relatively flat. This divergence suggests that the rising crude mortality may be influenced by an aging population, more than an increase in the risk of death from cancer.

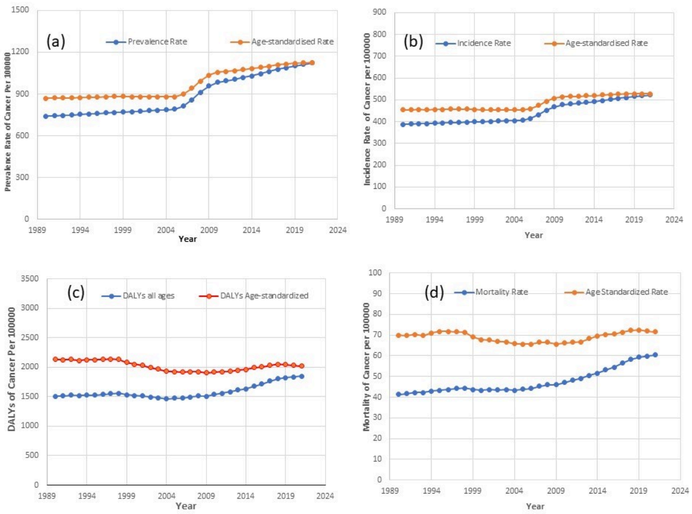

Figure 2: Cancer Trends in India (1990-2021): Prevalence and Age-Adjusted Prevalence Rates (a), Incidence and Age-Adjusted Incidence Rates (b), Observed and Age-Adjusted Disability-Adjusted Life Years (DALYs) Rates (c) and Mortality and Age-Adjusted Mortality Rates (d).

In Table 2, the analysis was employed to discern alterations in the occurrence, frequency, DALYs, and fatality rates of cancer throughout the duration of the research. No significant statistical variation was observed in the incidence rate from 1990 to 2006 (APC* = 0.0; 95% CI: 0.0 to 0.0). The incidence rate increased significantly between 2006 and 2009 (APC* = 3.9; 95% CI: 3.7 to 4.1). The incidence rate increased at a slower rate between 2009 and 2021 (APC* = 0.3; 95% CI: 0.3 to 0.4). There was a statistically significant increase in the prevalence rate between 1990 and 2006 (APC* = 0.1; 95% CI: 0.1 to 0.2). The prevalence rate increased significantly between 2006 and 2009 (APC* = 5.6; 95% CI: 5.4 to 5.9). The prevalence rate increased at a slower rate between 2009 and 2021 (APC* = 0.7; 95% CI: 0.6 to 0.7). There was a statistically significant decrease in DALYs between 1990 and 1998 (APC* = -1.6; 95% CI: -1.8 to -1.5). There was a statistically significant decrease in DALYs between 2004 and 2011 (APC* = -0.1; 95% CI: -0.3 to 0.0). The trend in DALYs is between 2011 and 2018 (APC* =1; 95% CI: 0.9 to 1.2) * . There was a statistically significant increase in the mortality rate between 1990 and 1997 (APC* = 0.5; 95% CI: 0.2 to 0.8). The mortality rate decreased significantly between 1997 and 2002 (APC* = -1.6; 95% CI: -2.5 to -1.1). There was no statistically significant change in the mortality rate between 2002 and 2021 (APC* = -0.1; 95% CI: -0.1 to 0.1).

Table 2: Trends in Cancer Burden in India using Joinpoint Regression Analysis (1990-2021).

Age Rate	Standardised	Incidence	Age Prevalence	Standardised	Age DALYs	Standardised	Age Rate	Standardised	Mortality

Segment	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)
1	1990-2006	0 (0.0 to 0.0) *	1990-2006	0.12 (0.1 to 0.2) *	1990-1998	0 (-0.1 to 0.1) *	1990-1997	0.5 (0.2 to 0.8) *
2	2006-2009	3.9 (3.7 to 4.1) *	2006-2009	5.6 (5.4 to 5.9) *	1998-2004	-1.6 (-1.8 to -1.5) *	1997-2002	-1.6 (-2.5 to -1.1) *
3	2009-2021	0.3 (0.3 to 0.4) *	2009-2021	0.7 (0.6 to 0.7) *	2004-2011	-0.1 (-0.3 to 0.0) *	2002-2010	-0.1 (-0.5 to 0.4) *
4					2011-2018	1 (0.9 to 1.2) *	2010-2018	1.2 (1 to 2.1) *
5					2018-2021	-0.5 (-0.9 to -0.1) *	2018-2021	-0.4 (-1.6 to 0.4)
AAPC*	1990-2021	0.5 (0.5 to 0.5) *	1990-2021	0.9 (0.8 to 0.9) *	1990-2021	-0.2 (-0.2 to -0.1) *	1990-2021	0.1 (0 to 0.1) *

Note: *, Indicates that the APC and AAPC are significantly different from zero at the alpha = 0.05 level. C.I.: confidence interval

In Figure 3, the graphs show a consistent increase in both cancer prevalence and incidence rates over the three decades, with significant jumps observed around the years 2006-2009. APC in prevalence rate increased dramatically from 0.12% (1990-2006) to 5.64% (2006-2009) and then moderated to 0.67% (2009-2021). Similarly, the incidence rate rose sharply from 0.01% (1990-2006) to 3.92% (2006-2009), before settling at 0.31% (2009-2021).

This figure depicts the DALYs rate for cancer, which demonstrates a notable decrease from 1990 until around 2004, after which it begins a fluctuating pattern. The initial decline (APC of -1.60 from 1998-2004) reflects improvements in healthcare outcomes or effective interventions during that time. However, from 2004 onward, the trend oscillates, suggesting varying success in cancer management and possibly changes in disease burden or health policies impacting DALYs. The cancer mortality rate, which appears to follow a U-shaped curve, initially decreasing (APC of -0.46 from 1990-1997), then increasing (APC of 1.21 from 1997-2010), and finally showing a slight decrease again (APC of -0.42 from 2010-2021). This pattern could be influenced by several factors including advancements in medical treatment, aging population, and other socio-economic factors that affect overall health outcomes.

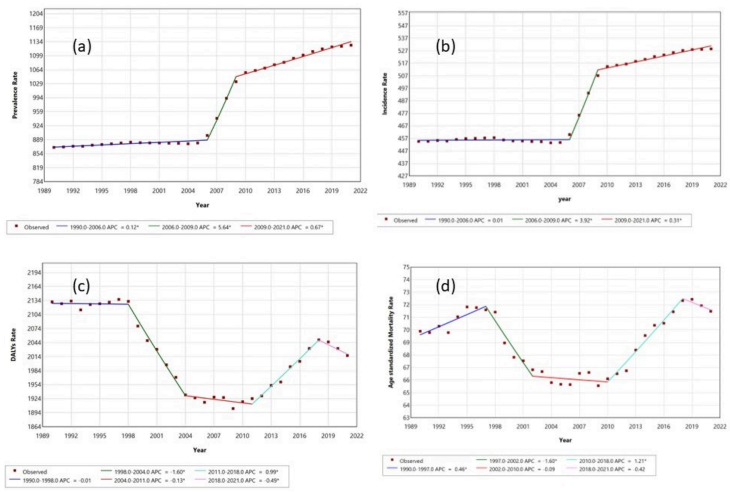

Figure 3: Joinpoint Regression Analysis of Cancer Trends in India

(1990-202) joinpoint analysis of trends in cancer prevalence rate (a), cancer incidence rate (b), cancer-related DALYs (Disability-Adjusted Life Years) (c) and cancer mortality rate (d).

Cancer prevalence across India from 1990 to 2021 reveals a significant variation between states. **Figure 4** depicts this geographical spread using a colour scheme where darker shades represent higher cancer prevalence rates per 100,000 people. Southern states like Karnataka (1396.34) and Kerala (1330.02) along with some northeastern states like Mizoram (1236.69) stand out with the highest prevalence rates. Conversely, Tripura (1003.63) exhibits the lowest prevalence among the states surveyed. Interestingly, the annual percentage change in prevalence also shows geographical disparity. Southern states, particularly Kerala (0.43), hold the distinction for having the highest annual increase. Delhi and Gujarat (0.36) follow closely behind. On the other end of the spectrum, states like Bihar (0.21), Jharkhand, and Chhattisgarh (0.24) experienced the slowest annual increase in prevalence.

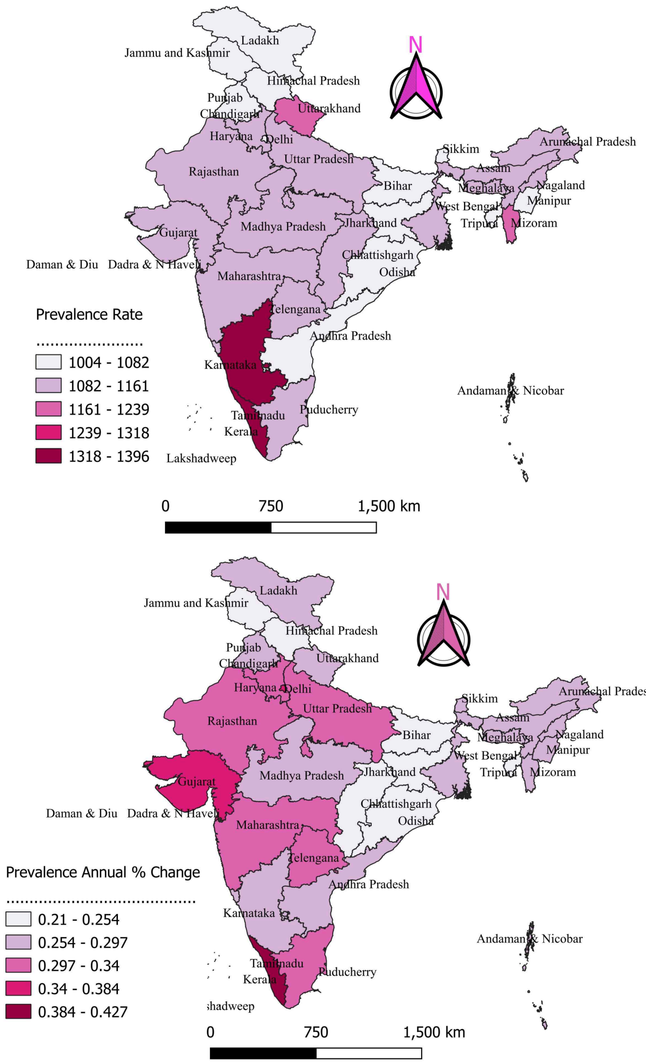

Figure 4: Prevalence of cancer among all age groups (top) and Annual Percentage Change (APC) in prevalence (bottom) in India_1990 to2021.

Figure 5. paints a similar picture of geographical variation, but this time focusing on incidence rates instead of prevalence. Here, we see the highest rates of new cancer cases per 100,000 people concentrated in the northeast, with Mizoram leading the way at 600.32, followed closely by Karnataka (599.28). Conversely, Bihar emerges with the lowest incidence rate among the surveyed states, followed by Jharkhand at 499.21. The data also reveals interesting trends in annual percentage change of incidence rates between 1990 and 2021. Gujarat takes the top spot for experiencing the fastest rise in new cases, with an annual increase of 0.20. Kerala (0.19) and

Uttar Pradesh (UP) come in a close second. Jharkhand, on the other hand, witnessed the slowest increase in incidence rates (0.10), with Bihar following slightly behind at 0.12.

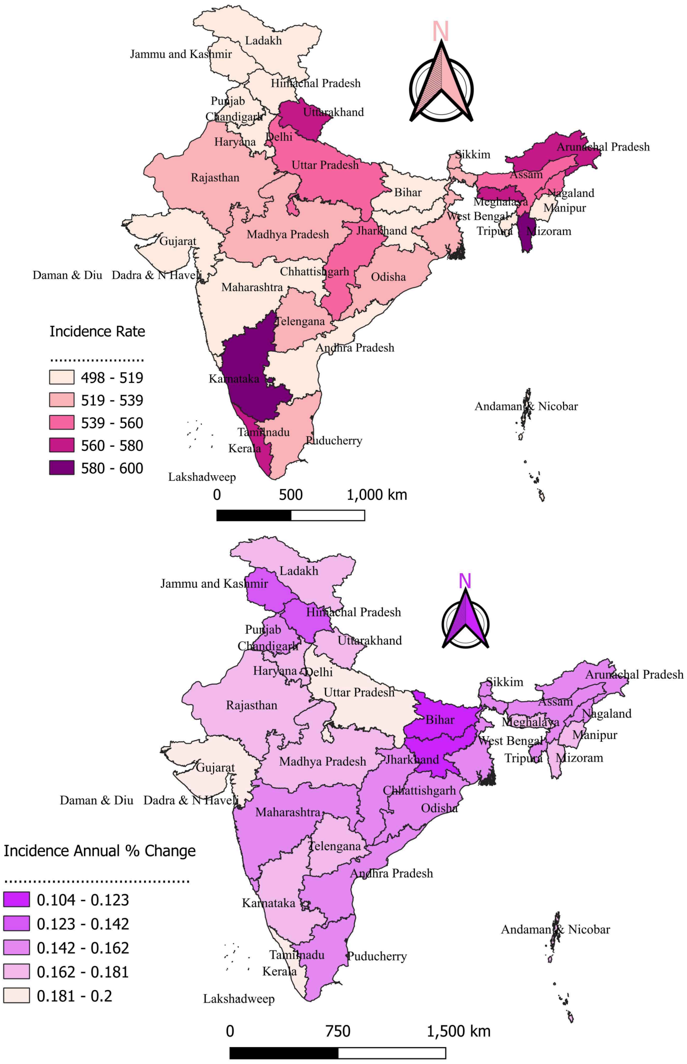

Figure 5: Incidence Rate of cancer among all age groups (top) and Annual Percentage Change (APC) in Incidence Rate (bottom) in India_1990 to 2021

Figure 6 dives deep into the state wise burden of cancer in India, using DALYs rates to represent the impact of the disease in 2021. The analysis reveals a clear geographical disparity. Northeastern states bear the brunt of the highest DALYs rates, with Mizoram (3641.96) leading the pack, followed by Meghalaya (3394.19) and Arunachal Pradesh (3102.37). Conversely, Jharkhand (454.66) experiences the lowest burden, alongside Goa (1424.71) and Andhra Pradesh (1399.86). Notably, the age standardised DALYs rate in India during 2021 was 2016.33.

The figure also presents a map highlighting the trends in annual % change in DALYs rate of cancer burden from 1990 to 2021. This period witnessed a positive development, with 20 states and union territories registering a decline in DALYs rates, signifying a negative annual percentage change. This includes states like Arunachal Pradesh (-0.074), Andhra Pradesh (-0.179), Delhi (-0.139), Kerala (-0.0343), Maharashtra (-0.079), and many others. However, the remaining states and union territories experienced an increase in DALY rates, reflected by a positive annual percentage change. Gujarat stands out with the highest change (0.237), followed by Uttar Pradesh (0.112) and Manipur (0.0405). This contrast underscores significant regional disparities in the burden of cancer and its trends over time in India.

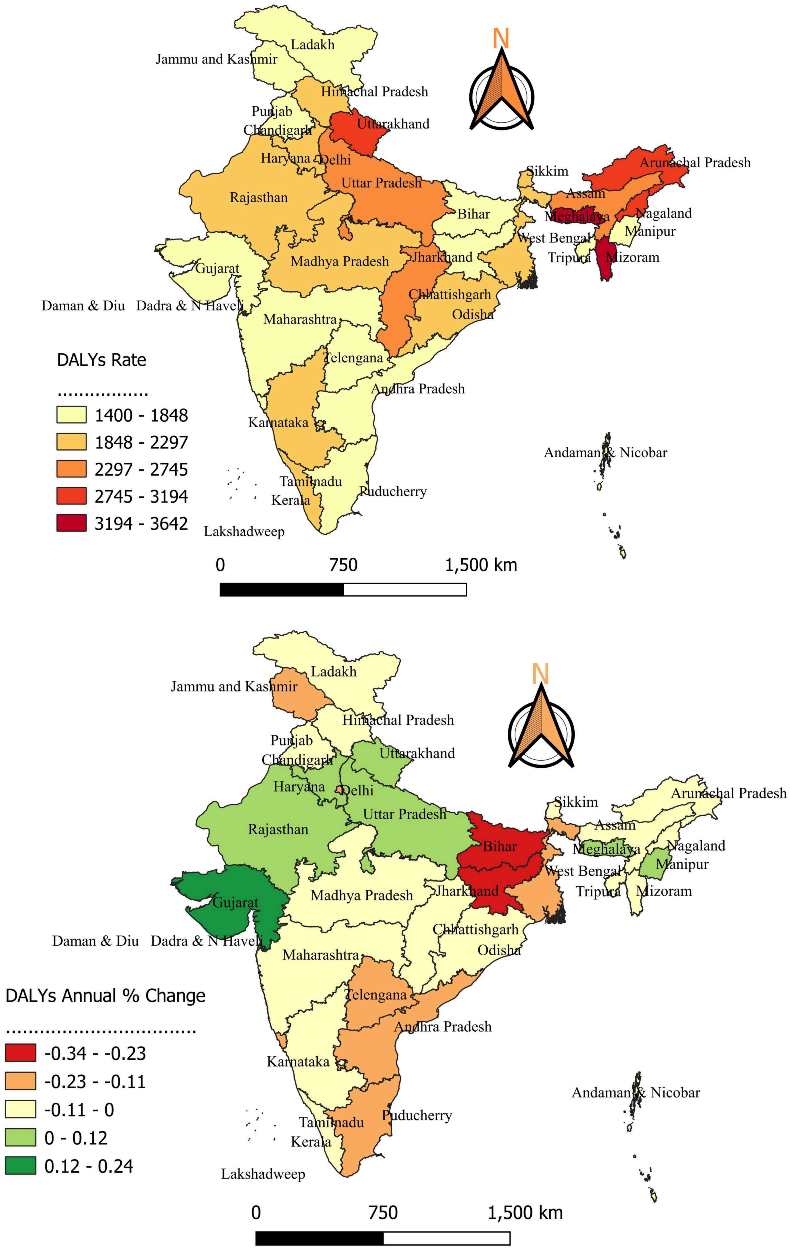

Figure 6: DALYs (top) and Annual Percentage Change (APC) in DALYs rate (bottom) of cancer among all age groups in India_1990 to2021.

Figure 7 elucidates the age-standardized mortality rate (ASMR) per 100,000 individuals for the burden of cancer in India in the year 2021. This metric highlights the mortality impact across different age groups. Similar to the DALYs rates, a distinct geographical pattern emerges. Northeastern states once again face a heavier burden, with Mizoram (140.08) having the highest ASMR, followed by Meghalaya (125.86) and Arunachal Pradesh (116.83). Conversely, Jharkhand (52.33) experiences the lowest mortality rate, along with Goa (52.10) and Andhra Pradesh (50.54).

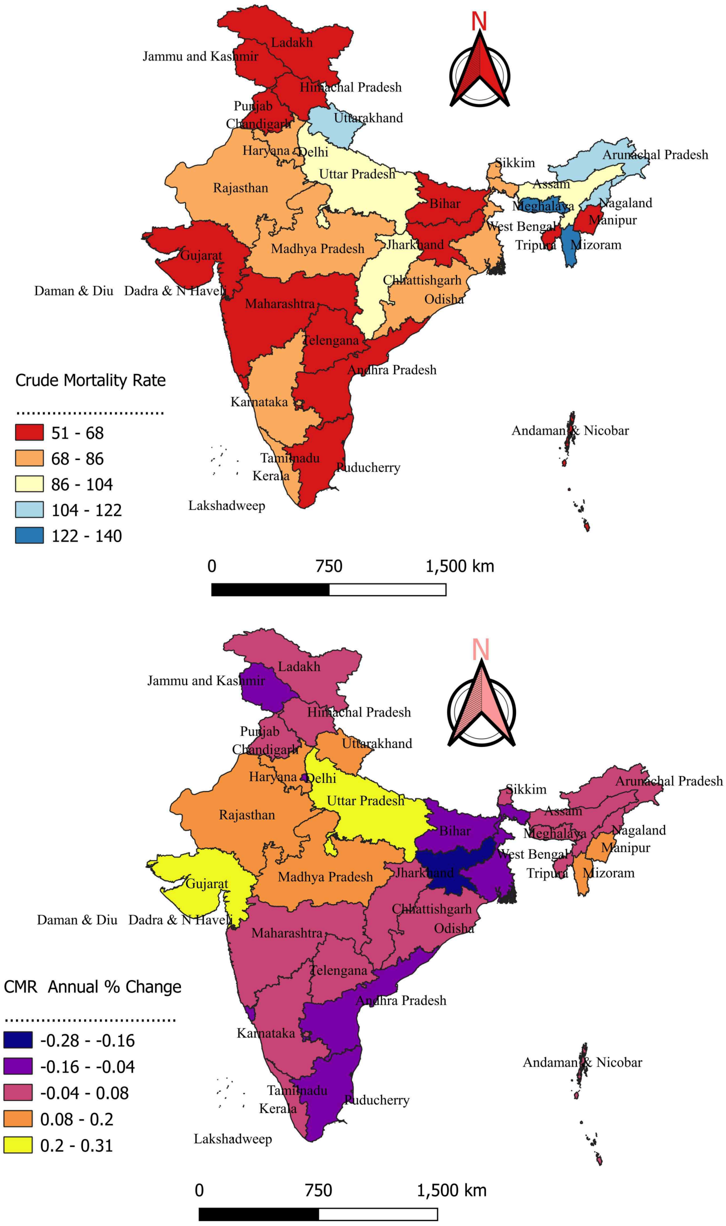

Figure 7: Crude Mortality Rate (top) and Annual Percentage Change (APC) in Crude Mortality Rate (bottom) of cancer among all age groups in India_1990 to2021.

The figure also explores the annual percentage change in ASMR between 1990 and 2021. While some states grapple with a rising burden, others show positive progress. Gujarat exhibits the most significant increase (0.31), followed by Uttar Pradesh (0.21) and Manipur (0.11). Encouragingly, 13 states and union territories witnessed a decline in ASMR, reflected by negative annual percentage changes. This includes states like Punjab, Tripura, Maharashtra, Goa (with a -0.02 change), Bihar (-0.13), and Jharkhand with the most substantial decrease (-0.21). These declines indicate a positive trend in reducing cancer mortality rates in these regions.

Figure 8. presents a comprehensive heatmap depicting the age-standardized DALYs rates for various cancer types across Indian states in 2021. The heatmap is organized in such a way that the columns represent different states and union territories in India, while the rows represent different types of cancer. Each cell in the heatmap is color-coded with numerical values indicating the specific burden score (ranked in descending order red to green) based on the DALYs rates, allowing for an immediate visual assessment of cancer burden across different states of India. This comparative plot highlights specific cancers such as breast, cervical, stomach, tracheal, bronchus, and lung cancer with high DALYs rates across many states in India. On the other side, cancers such as eye, neuroblastoma, other neoplasm, and testicular cancer show lower DALYs

Rates across most states of India. The heatmap effectively highlights the variation in cancer burden across different regions in India and emphasizes the need for targeted public health strategies to address the specific cancer types that are more prevalent in certain areas. This data can be used by health authorities to prioritize and tailor cancer prevention and treatment programs to the regional needs.

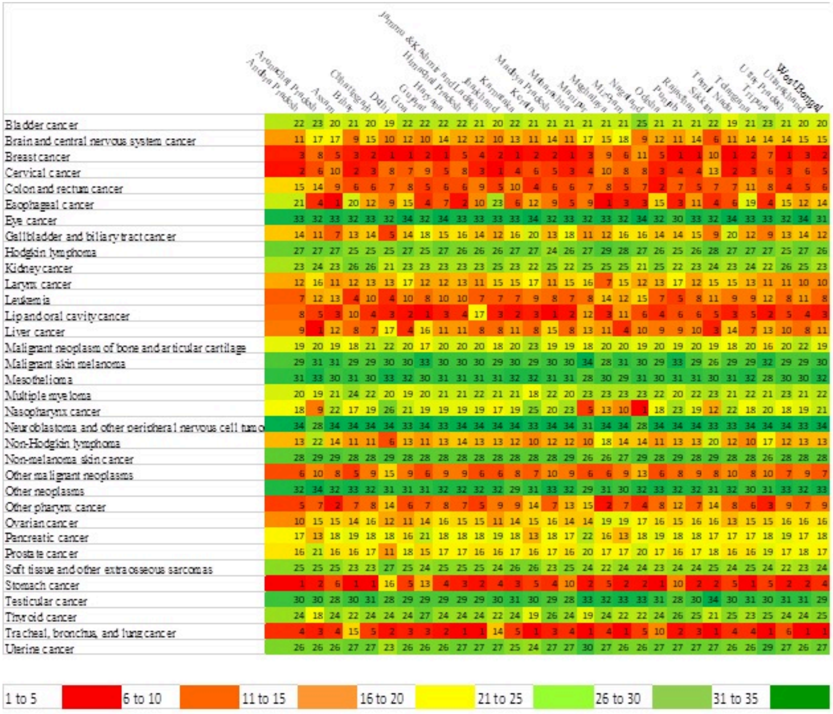

Figure 8: Heatmap of Cancers ranked by Age-Standardized DALYs Rate Across Indian States, 2021 (in descending order).

Figure 9 illustrates the changes in the rankings and DALYs rates of 34 types of cancer in India, comparing data from 1990 to 2021. Out of the 34 types of cancers, 11 improved in rank (experienced a decrease in DALYs rate), 20 deteriorated (experienced an increase in DALYs rate), and the remaining 3 remained unchanged. Breast cancer replaced cervical cancer as the top ranked cancer by DALYs rate in 2021. The highest annual percent rised in the burden of multiple myeloma (0.64%) followed by ovarian cancer (0.54%) between 1990 and 2021.The shifting landscape of cancer burden in India underscores the need for adaptive healthcare strategies tailored to the evolving patterns of disease prevalence.

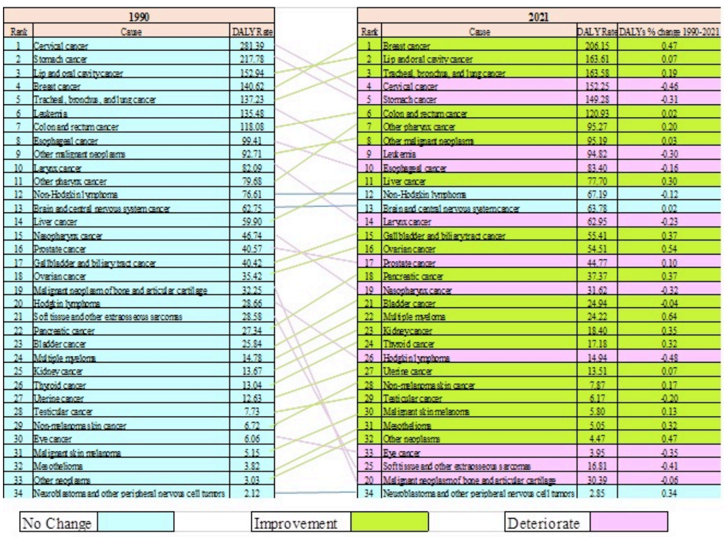

Figure 9: Change in the rank of types of cancer in terms of DALY age standardise rate in India, 1990-2021.

Discussion

Overall, the burden of all ages of cancer in India demonstrably increased from 1990 to 2021, with prevalence, incidence, DALYs, and mortality rates all exhibiting upward trends. All metrics show a steeper rise in elderly age groups, highlighting a population segment disproportionately affected by the growing cancer burden, which has been a matter of concern since last three decades [18, 19]. This necessitates age-standardized analyses to accurately compare the burden across populations with varying age structures and identify potential risk factors specific to different age demographics. The complex dynamics of cancer trends in India, showcasing both progress and challenges in cancer control over the period from 1990 to 2021. Some northeastern states, show the highest annual increase, suggesting not only a higher burden of cancer but also a faster growing rate compared to the rest of the country. This visualization highlights regional disparities in cancer burden across India, indicating areas where healthcare systems may need to bolster oncological services and prevention programs.

The joinpoint analysis shows a complex picture of cancer burden trends over the past three decades. While the incidence and prevalence of cancer have increased, there has also been a decrease in DALYs and mortality rates in some time periods. The joinpoint analysis helps to pinpoint years where significant changes in trends occurred, providing insights into the effectiveness of health interventions and changes in public health policies This suggests that improvements in cancer prevention, screening, and treatment may be leading to better outcomes for cancer patients. Joinpoint analysis of SEER data reveals rising incidence and mortality trends in most gynecological cancers among elderly US women (1975-2020), except for a decrease in cervical cancer incidence and mortality [20].

The comparative analysis of geographical aera and the cancer type highlights specific cancers such as breast, cervical, stomach, tracheal, bronchus, and lung cancer with universally high DALYs rates across many states in India. These type of cancers constantly showes higher DALYs from the year 2019 across different states of India [18]. On the other hand, cancers like eye, neuroblastoma, other neoplasm and testicular cancer shows lower DALYs rates across most states. It highlights the successes and challenges in cancer management and underscores the critical need for focused health policies to address the diverse and changing patterns of cancer prevalence.

In 2018, cancer is estimated to cause nearly 18 million new cases and 10 million deaths worldwide, with lung cancer being the most common and deadly overall. From a previous study we observed Breast, Cervical and Stomach cancer are the top 3 cancers among female and Lung, Stomach and Pharynx cancer are the top 3 cancers among males causing the highest number of deaths in India [7]. The cancer burden varies greatly by region and income level, highlighting the need for improved cancer data collection in low- and middle-income countries [5].Overall, the cancer burden in India has increased substantially since 1990 [7]. However, the incidence rate of some cancers has decreased, while the rate of others has increased. Tobacco use is the leading risk factor for cancer in India [7, 21, 22].

DALYs rates for stomach, cervical, larynx, nasopharynx cancers, chronic myeloid leukemia, other leukemias, and Hodgkin lymphoma have all dropped by more than 1% annually [23-25]. Several studies suggest a link between the decline in stomach cancer rates in India and improvements in living standards [8, 26]. A study found a high burden of breast cancer, varying by region, with an estimated 515.4 DALYs per 100,000 women and a projection of a substantial increase to 5.6 million DALYs by 2025 in India [10]. The elderly (60+) experience the highest prevalence of cancer, with rates varying across regions (highest in Karnataka, lowest in Jharkhand). Cancer prevalence among the elderly has increased significantly since 1990, with Kerala showing the fastest rise. Individuals aged 80-84 have the highest burden of disability due to cancer. Lung, colon, stomach, breast, and lip/oral cavity cancers are the most impactful among elderly Indians. These findings highlight the growing vulnerability of elderly Indians to cancer and emphasize the need for state-specific interventions to reduce cancer risk in this age group [18]. These findings highlight the growing vulnerability of elderly Indians to cancer and emphasize the need for state-specific interventions to reduce cancer risk in this age group.

Limitation

While the current analysis provides a population-level assessment of cancer burden in India through incidence, prevalence, DALYs, and mortality metrics, its generalizability is limited by a lack of granularity. The exclusion of etiological factors (risk factors) and cancer-specific trends hinders a deeper understanding of the underlying drivers of these trends. Furthermore, the focus on aggregate data masks potential heterogeneity in cancer burden across age strata. This impedes the identification of high-risk populations who may require targeted interventions or preventive strategies. Additionally, the reliance on joinpoint regression, although adept at detecting significant changes in trends, offers limited explanatory power regarding the etiology of these shifts. Consequently, by neglecting to incorporate a disaggregated analysis of risk factors, cancer types, and age groups, the study presents a high-level overview but fails to pinpoint specific areas for targeted public health initiatives in India. Future research on cancer burden in India should prioritize disaggregated analyses of risk factors, cancer types, and age groups to identify high-risk populations and elucidate the drivers behind observed trends.

Conclusion

India's cancer burden has grown considerably between 1990 and 2021. This analysis identified a worrying increase in new cases, existing cases, impact on people's lives (DALYs), and deaths. The study also revealed periods of more dramatic growth and times of stabilization. Furthermore, it highlighted the uneven distribution of this burden across different regions in India. Understanding these trends is vital for creating effective programs to control cancer. The rising number of cases suggests a need for public health initiatives that focus on preventing cancer in the first place. This could involve encouraging healthy lifestyles, promoting vaccinations against cancer-causing viruses, and reducing exposure to environmental risks. The increasing number of existing cases and the impact on people's lives (DALYs) highlight the growing population living with cancer and the significant challenges they face. Implementing affordable screening strategies for common cancers can lead to earlier diagnosis and treatment, improving patient outcomes and reducing long-term disability. The analysis of regional variations allows policymakers to target interventions toward the areas most affected by cancer. These areas require increased investment in healthcare infrastructure and access to specialized cancer care. Additionally, raising awareness and educating communities about cancer risk factors and symptoms can encourage timely diagnosis and improve overall health knowledge.

Supporting information

None

Ethical Considerations

None

Acknowledgments

None

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author contribution statement

All authors contributed equally and attest they meet the ICMJE criteria for authorship and gave final approval for submission

Data availability statement

Data included in article/supp. material/referenced in article.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Mallath MK, Taylor DG, Badwe RA, Rath GK, Shanta V, Pramesh C, et al. The growing burden of cancer in India: epidemiology and social context. Lancet Oncol. *2014;15(6):e205-e12 [Crossref][PubMed][Google Scholar]*

2. Ferlay J, Colombet M, Soerjomataram I, Mathers C, Parkin DM, Piñeros M, et al. Estimating the global cancer incidence and mortality in 2018: GLOBOCAN sources and methods. Int J Cancer. *2019;144(8):1941-53 [Crossref][PubMed][Google Scholar]*

3. Yancik R. Population aging and cancer: a cross-national concern. The Cancer J. *2005;11(6):437-41 [Crossref][PubMed][Google Scholar]*

4. Lin L, Yan L, Liu Y, Yuan F, Li H, Ni J. Incidence and death in 29 cancer groups in 2017 and trend analysis from 1990 to 2017 from the Global Burden of Disease Study. J Hematol Oncol. *2019;12:1-21 [Crossref][PubMed][Google Scholar]*

5. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. *2018;68(6):394-424 [Crossref][PubMed][Google Scholar]*

6. Farmer P, Frenk J, Knaul FM, Shulman LN, Alleyne G, Armstrong L, et al. Expansion of cancer care and control in countries of low and middle income: a call to action. The Lancet. *2010;376(9747):1186-93 [Crossref][PubMed][Google Scholar]*

7. Dhillon PK, Mathur P, Nandakumar A, Fitzmaurice C, Kumar GA, Mehrotra R, et al. The burden of cancers and their variations across the states of India: the Global Burden of Disease Study 1990–2016. Lancet Oncol. *2018;19(10):1289-306 [Crossref][PubMed][Google Scholar]*

8. Dikshit R, Gupta PC, Ramasundarahettige C, Gajalakshmi V, Aleksandrowicz L, Badwe R, et al. Cancer mortality in India: a nationally representative survey. The Lancet. *2012;379(9828):1807-16 [Crossref][PubMed][Google Scholar]*

9. Takiar R, Nadayil D, Nandakumar A. Projections of number of cancer cases in India (2010-2020) by cancer groups. Asian Pac J Cancer Prev. *2010;11(4):1045-9 [Crossref][PubMed][Google Scholar]*

10. Kulothungan V, Ramamoorthy T, Sathishkumar K, Mohan R, Tomy N, Miller G, et al. Burden of female breast cancer in India: estimates of YLDs, YLLs, and DALYs at national and subnational levels based on the national cancer registry programme. Breast Cancer Research and Treatment. *2024:1-10 [Crossref][PubMed][Google Scholar]*

11. Gupta B, Ariyawardana A, Johnson NW. Oral cancer in India continues in epidemic proportions: evidence base and policy initiatives. Int Dent J. *2013;63(1):12-25 [Crossref][PubMed][Google Scholar]*

12. Bajpai V. The challenges confronting public hospitals in India, their origins, and possible solutions. Adv Public Health. *2014;2014(1):898502 [Crossref][PubMed][Google Scholar]*

13. Gandhi AK, Kumar P, Bhandari M, Devnani B, Rath GK. Burden of preventable cancers in India: Time to strike the cancer epidemic. J Egypt Natl Canc Inst. *2017;29(1):11-8 [Crossref][PubMed][Google Scholar]*

14. Global Burden of Disease Study 2021. Institute for Health Metrics and Evaluation (IHME). Available from: https://vizhub. *healthdata.org/gbd-compare/india; 2021. Accessed June 25, 2024 [Crossref][PubMed][Google Scholar]*

15. Mathur P, Sathishkumar K, Chaturvedi M, Das P, Sudarshan KL, Santhappan S, et al. Cancer statistics, 2020: report from national cancer registry programme, India. JCO Glob Oncol. *2020;6:1063-75 [Crossref][PubMed][Google Scholar]*

16. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. Stat Med. *2000;19(3):335-51 [Crossref][PubMed][Google Scholar]*

17. Kim S, Lee S, Choi JI, Cho H. Binary genetic algorithm for optimal joinpoint detection: application to cancer trend analysis. Stat Med. *2021;40(3):799-822 [Crossref][PubMed][Google Scholar]*

18. Swain CK, Padhee S, Sahoo U, Rout HS, Swain PK. Changing patterns of cancer burden among elderly across Indian states: Evidence from the global burden of disease study 1990–2019. Aging Med. *2023;6(3):254-63 [Crossref][PubMed][Google Scholar]*

19. Fitzmaurice C, Collaboration GBoDC. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 2006 to 2016: A systematic analysis for the Global Burden of Disease study. American Society of Clinical Oncology; 2018. *[Crossref][PubMed][Google Scholar]*

20. Priyadarshini S, Swain PK, Agarwal K, Jena D, Padhee S. Trends in gynecological cancer incidence, mortality, and survival among elderly women: A SEER study. Aging Med. *2024 [Crossref][PubMed][Google Scholar]*

21. Nath A, Barman D, Sharma A, Lahon R, Misra C. Prevalence of obesity and physical inactivity in Assam, India: Findings from cancer risk factor monitoring survey. Ann Oncol Res Ther. *2024;4(1):20-5 [Crossref][PubMed][Google Scholar]*

22. Michaelraj MJ, Kuttiappan K, Ramasamy S, Rodrigues FAE, Govindaraj S. Demographic profile and risk factors of head-and-neck squamous cell carcinoma in west Tamil Nadu: A cross-sectional observational study. Cancer Res Stat Treat. *2023;6(2):215-23 [Crossref][PubMed][Google Scholar]*

23. Singh M, Jha RP, Shri N, Bhattacharyya K, Patel P, Dhamnetiya D. Secular trends in incidence and mortality of cervical cancer in India and its states, 1990-2019: data from the Global Burden of Disease 2019 Study. BMC cancer. *2022;22(1):149 [Crossref][PubMed][Google Scholar]*

24. Dhillon P, Yeole B, Dikshit R, Kurkure A, Bray F. Trends in breast, ovarian and cervical cancer incidence in Mumbai, India over a 30-year period, 1976–2005: an age–period–cohort analysis. Br J Cancer. *2011;105(5):723-30 [Crossref][PubMed][Google Scholar]*

25. Sullivan R, Badwe RA, Rath GK, Pramesh C, Shanta V, Digumarti R, et al. Cancer research in India: national priorities, global results. Lancet Oncol. *2014;15(6):e213-e22 [Crossref][PubMed][Google Scholar]*

26. Kono S, Ikeda M, Ogata M. Salt and geographical mortality of gastric cancer and stroke in Japan. J Epidemiol Community Health. *1983;37(1):43-6 [Crossref][PubMed][Google Scholar]*

Disclaimer / Publisher's Note