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Trends and patterns in dengue incidence and mortality across India and its states from 1990 to 2019: insights from the Global Burden of Disease Study 2019

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Evidence in Context

- Dengue incidence increased modestly, while mortality decreased in India.
- Regional disparities were noted, with declining incidence in states like Delhi, and rising mortality in Assam and Odisha.
- Urbanization, socioeconomic factors, and climate influenced dengue trends.
- Enhanced diagnostic capabilities likely contributed to reduced mortality.
- Tailored regional strategies are essential for effective dengue control.

To view Article

Abstract

Background: The upsurge in the dengue cases presents significant challenge to the public health systems, with an estimated 390 million infections yearly. This study examines the trends and patterns in dengue incidence and mortality in India in the period 1990-2019.

Methods: Information regarding the incidence and mortality rates of dengue from 1990-2019 was obtained from the Global Burden of Disease Study 2019. The analysis of changes across time and place was done using a geographic map of age-standardized rates. Joinpoint regression analysis was used to identify key periods of change.

Results: The study found that India's age-standardized incidence rate (ASIR) of dengue shows a modest Average Annual Percent Change (AAPC) of 0.14% (95% CI: 0.12 to 0.15), lower than global and South Asian rates. The age-standardized death rate (ASDR) in India is decreasing, with an AAPC of -0.80% (95% CI: 0.69 to 0.89), contrasting with the increasing trend in South Asia. Regional disparities within India were evident with states like Delhi, Jharkhand and Tripura experiencing a decline in incidence, while states such as Assam, Goa, and Odisha showed an increase in mortality rates.

Conclusion: Despite a modest increase in incidence, India has achieved a reduction in mortality rates, indicating progress in dengue control. However, the persistence of regional disparities highlights the need for tailored public health strategies. This study emphasizes the importance of continuous monitoring, region-specific interventions, and alignment with the Sustainable Development Goals, to effectively combat dengue in India and contribute to global dengue control efforts.

Keywords: *Dengue, incidence, mortality, trend, joinpoint regression analysis, GBD, India*

Introduction

Dengue, a viral infection, has become a significant public health challenge due to the global increase in dengue cases in recent decades. It is estimated that annually, dengue leads to around 390 million infections and about 20,000 fatalities [1]. According to the World Health Organization, nearly 3.97 billion individuals across 128 countries are susceptible to dengue, with an estimated 50 million cases occurring each year [1, 2]. Globally, the incidence of dengue has multiplied nearly eightfold from 1990 to 2019 [3] and 30- fold since the 1960s [4], with considerable geographic expansion and is a pandemic threat in tropical and subtropical regions. During 2000-2015, the deaths due to dengue rose from 960 to 4,032[3]. This surge is attributed to factors like rapid urbanization, climate change, and increased international travel, all of which create favorable conditions for the Aedes mosquito vectors that transmit the virus. Bhatt et al. found its ubiquitous presence in the tropics, with significant local variations attributable to factors such as rainfall, temperature, and urbanization[1]. Their findings suggested a far higher number of dengue infections globally than previously estimated by the World Health Organization, thus redefining the perceived public health burden of dengue. Studies show that the lack of vaccines and insufficient vector control measures, has contributed to the disease's rapid emergence and global spread [1].

Globally, the distribution and burden of dengue have been a subject of extensive research. A systematic analysis of the global dengue burden from 1990 to 2017, revealed a significant increase in both the incidence and mortality associated with dengue [5]. This increase, coupled with variations in socio-demographic indices, suggests that has varying impacts across different regions and socio-economic contexts highlighting its spread at a global level. Gubler discussed the dramatic increase in these diseases over the past two decades, attributing the resurgence to a combination of ecological, environmental, and sociodemographic changes [2]. This trend is particularly alarming in India, a country with a long history of dengue outbreaks.

Dengue is characterized by its complex transmission dynamics, which involve interactions among the host, the vector, and the virus, and are significantly influenced by environmental and climatic factors [2, 4]. Mutheneni et al. underscored the variability in extrinsic incubation period (EIP) across diverse climatic conditions, which in turn affects regional dengue risk in different climatic zones of India [4]. For instance, the state of Kerala demonstrated a notably faster EIP during the monsoon period, correlating with increased dengue cases. Such findings emphasize the necessity for climate-specific disease forecasting models in dengue-prone areas.

The quantification of dengue infection load in different parts of India is limited. The burden of dengue infection across geographical regions of India is poorly quantified[6]. With its dense population and tropical climate, India experiences a substantial burden of dengue cases annually [2] making it a dengue epidemic country. There were 94198 dengue cases in India between January and October 2022 [7]. As to the latest available statistics, there were 110,473 cases of dengue reported in India between January and September of 2023 [8]. The patterns and characteristics of dengue fever in the Indian subcontinent have undergone significant and complex changes over the last sixty years, including variations in dominant strains, impacted regions, and the severity of the illness [9]. Researchers estimated the number of dengue infections to be substantially higher than the figures reported by the World Health Organization [1], underscoring the need for improved surveillance and reporting. This discrepancy points to a potential underestimation of the disease's true burden and highlights the necessity for enhanced disease control strategies.

In India, a country with diverse climatic conditions and varying socio-economic environments, dengue presents a significant public health challenge. The burden of dengue infection in India is heterogeneous, with evidence of high transmission in northern, western, and southern regions [6]. The dynamic nature of dengue transmission, geographic heterogeneity influenced by urbanization, climate change, and vector behavior, necessitates an in-depth analysis of temporal trends to understand the evolving epidemiology of the disease. Previous research has often been limited in scope, either geographically or temporally or in standard methodology to capture the regional heterogeneity[6, 7, 9, 10]. This study aims to bridge this gap by providing a comprehensive, long-term analysis at both the national and state levels. Such an analysis is crucial for effective public health planning and resource allocation. By identifying periods and locations of significant changes

In dengue trends, targeted interventions such as vector control, public awareness campaigns, and healthcare resource optimization can be effectively planned and implemented. This study aims to examine the trends in dengue incidence and mortality in India from 1990 to 2019 using joinpoint regression analysis.

Methods

Data on state-specific dengue incidence and mortality from 1990 to 2019 were sourced from the GBD India Compare tool (https://vizhub.healthdata.org/gbd-compare/india) (GBD India Compare Data Visualization). The global level data were retrieved from the Global Burden of Disease Study 2019 Global Health Data Exchange (GHDx) query tool from Institute for Health Metrics and Evaluation (IHME) website.

This study presents graphical representations of state-wise prevalence of dengue incidence and mortality at 10 year interval and change in overall ranking variations in dengue incidence and mortality. The analysis employed joinpoint regression to assess the extent of time trends in the age-standardized incidence and mortality rates of Dengue, calculating the Average Annual Percent Change (AAPC) and its 95% Confidence Interval (CI). This method pinpoints the years where trends shift and computes the annual percentage change (APC) for these intervals.

For APC estimation, the approach is as follows: If no joinpoint is detected over the study period, APC and AAPC are identical. If trend changes are observed, the period is divided at these points of change [11]. The AAPC is then determined as a geometric mean of the APCs obtained from regression analysis [12]. For our study's duration, the AAPC is derived using the optimal model, allowing up to 5 joinpoints, leading to a maximum of 6 segments. The joinpoint regression analysis was conducted using the Joinpoint Regression Program (version 4.9.0.0), supplied by the Surveillance Research Program of the US National Cancer Institute.

Results

Figure 1 delineates the temporal progression of Age-Standardized Incidence Rates (ASIR) of dengue per 100,000 population across three distinct geographic entities—India, South Asia, and the global landscape—over a span of three decades (1990-2019).

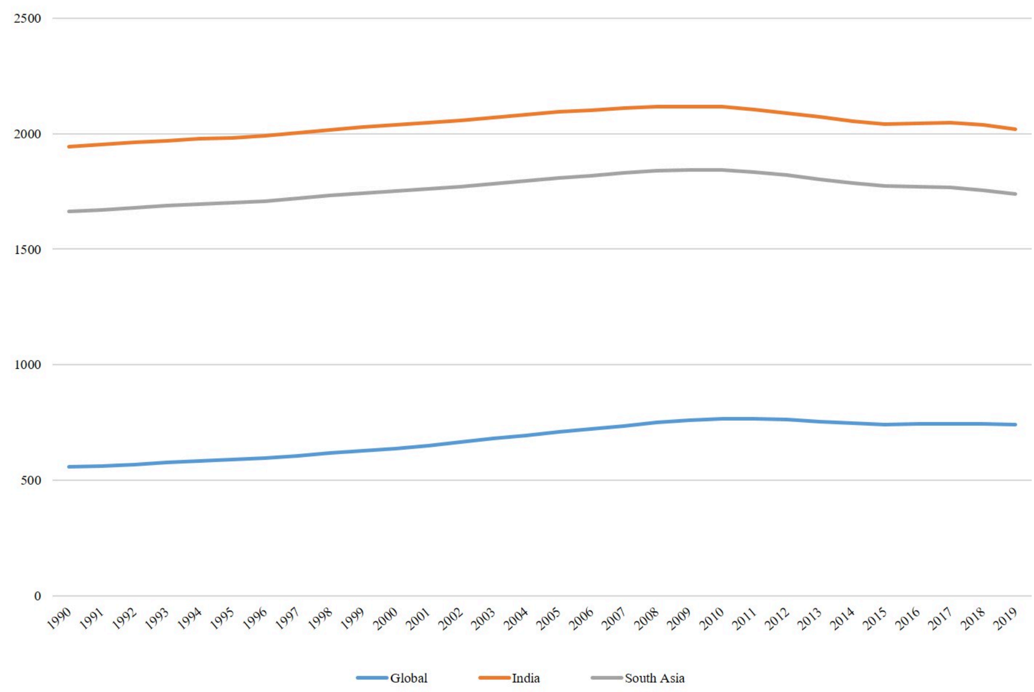


Figure. 1 Trends in the age-standardized incidence rates for Dengue per 100,000 population in India, South Asia and Global, 1990-2019

It elucidates a sustained ASIR in India, with marginal oscillations around a constant mean, indicating an endemic presence of dengue with no significant upward or downward trends with ASIR higher than global and South Asia. Concurrently, the South Asian ASIR, while persistently surpassing the global mean, also exhibits a plateau, reflective of a stable endemicity in the broader region. In stark contrast, the global ASIR remains markedly lower than its South Asian counterparts and demonstrates a horizontal trajectory over the years surveyed. Collectively, the data suggest a static endemicity of dengue within India and the South Asian belt, distinctly elevated above the global incidence rates, which have remained consistently lower and unfluctuating.

The graph (Figure 2) presents a comparative temporal analysis of Age-Standardized Death Rates (ASDR) of dengue per 100,000 individuals across three geospatial cohorts—India, South Asia, and the Global context—from 1990 through 2019. Notably, the data depict a stable trend in global dengue mortality rates (orange line), maintaining a value near 0.5 deaths per 100,000 population throughout the 30-year period. In contrast, the ASDR for South Asia (grey line) shows a modest elevation over the global rate, commencing at approximately 1 death per 100,000 population in 1990 and culminating at about 1.5 deaths by 2019, signaling a gentle but progressive increase. India's ASDR (blue line) oscillates closely with the South Asian trend but demonstrates a discernible uptick in the latter half of the observed timespan, suggesting an incremental rise in dengue-related mortality, potentially indicative of changing epidemiological patterns or variations in reporting accuracy. ASDR in India is quite higher than global and South Asia. The graph's portrayal of a relatively static global rate juxtaposed with a gradual ascension in the South Asian and Indian ASDR underscores the regional disparities in dengue mortality and may reflect differences in public health infrastructure, vector control measures, and healthcare access.

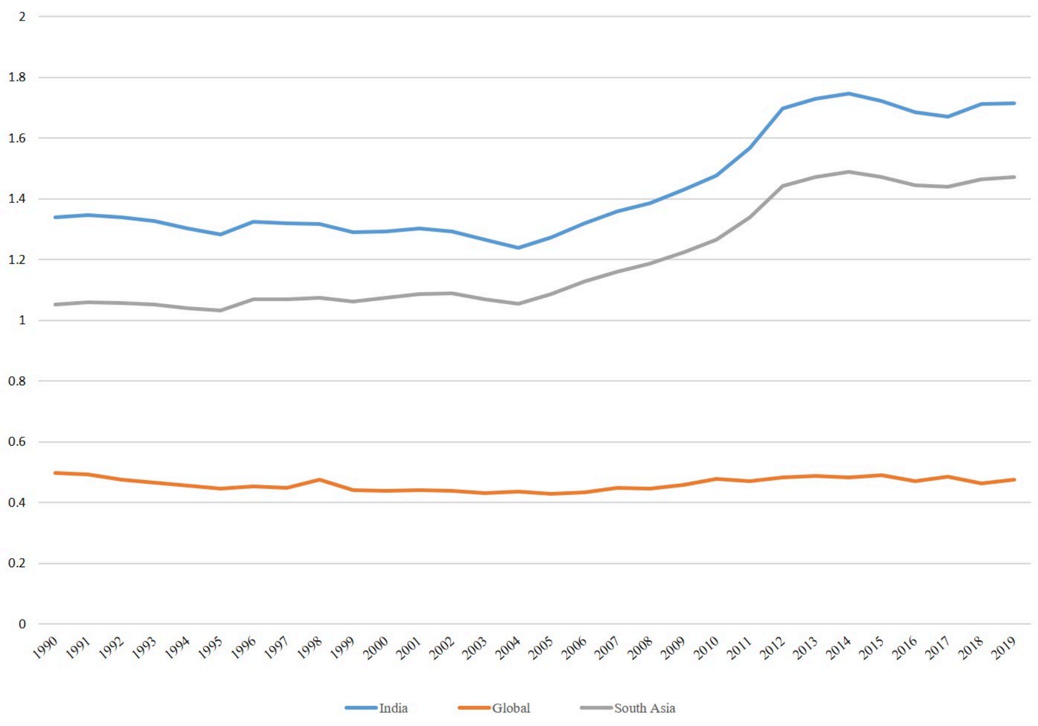


Figure. 2 Trends in the age-standardized death rates for dengue per 100,000 population in India, South Asia and Global, 1990-2019

To investigate the changes in dengue incidence and mortality trends, we have estimated the average APC. In ASIR the joinpont regression model identified 6 segments namely 1990-1996, 1996-2006, 2006-2010, 2010-2014, 2014-2017, 2017-2019. In Indian context, the changes in incidence were significantly pronounced in the period 1990-1996, 1996-2006, 2006-2010, 2017-2019 only. While for ASDR due to dengue, the identified segments were four i.e. 1990-2005, 2005-2010, 2010-2013, 2013-2019.

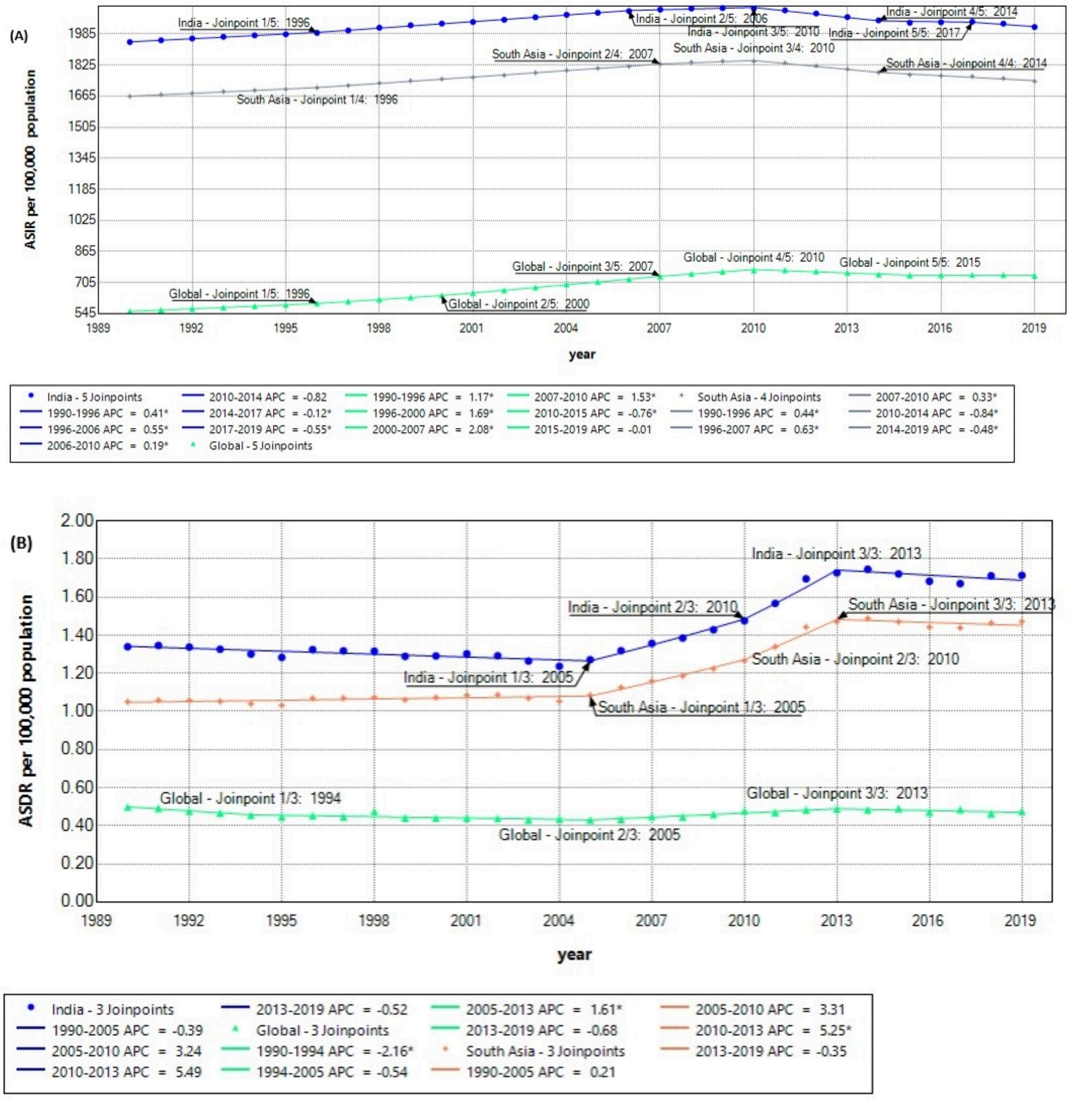


Figure 3: Trends in Age-Standardized rates of dengue per 100, 000 population in India. A) Incidence and B) Death Rates Using Joinpoint Regression Analysis across India and Global.

Table 1: Trends in dengue incidence in India, South Asia and Global from 1990 to 2019 using Joinpoint Regression Analysis

	Age Standardised Incidence rate (Global)		Age Standardised Incidence rate (India)		Age Standardised Incidence rate (South Asia)	
Segment	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)
1	1990-1996	1.17*(0.95,1.27)	1990-1996	0.41*(0.25,0.47)	1990-1996	0.44*(0.34,0.50)
2	1996-2000	1.69*(1.34,1.94)	1996-2006	0.55*(0.49,0.65)	1996-2007	0.63*(0.60-0.68)
3	2000-2007	2.08*(2.00,2.30)	2006-2010	0.19*(0.06,0.57)	2007-2010	0.33*(0.24,0.47)
4	2007-2010	1.53*(1.35,1.74)	2010-2014	-0.81(-0.96,0.19)	2010-2014	-0.83*(-0.97,-0.75)
5	2010-2015	-0.76*(-0.93,-0.63)	2014-2017	-0.12(-0.8,-0.01)	2014-2017	-0.48*(-0.55,-0.36)
6	2015-2019	-0.1(-0.18,-0.27)	2017-2019	-0.55*(-0.77, -0.27)		
AAPC*	1990-2019	0.99* (0.98, 1.01)	1990-2019	0.14* (0.12, 0.15)	1990-2019	0.16*(0.15,0.17)

*Note: *, Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level; # Indicates that the AAPC Difference is significantly different from zero at the alpha = 0.05 level; APC, annual percentage change; AAPC, average annual percent change; CI, confidence interval.*

Table 1 utilizes Joinpoint Regression Analysis to articulate the shifts in dengue incidence rates (IRs) across different regions. The global trend, starting from 1990 to 2019, exhibits an AAPC of 0.99% (95% CI: 0.98 to 1.01), indicative of a consistent increment. India's incidence rate reveals a modest AAPC of 0.14% (95% CI: 0.12 to 0.15), while South Asia's AAPC stands at 0.16% (95% CI: 0.15 to 0.17). The APC values for specific segments within the timeframe display a mix of incremental increases and decreases, with significant changes denoted by asterisks at the alpha = 0.05 level.

Dengue mortality trends, examined through the same analytical lens, show a global reduction in the AAPC of -0.21% (95% CI: -0.37 to -0.09) (Table 2). Contrastingly, the AAPC for India indicates a decline of -0.80% (95% CI: 0.69 to 0.89), while South Asia presents an increase of 1.13% (95% CI: 1.04 to 1.21). Segmental APC analysis from 1990 to 2019 underscores significant temporal variations, with some intervals marked by increases in mortality rates, particularly in South Asia between 2005 to 2013.

Table 2: Trends in dengue mortality in India, South Asia and Global from 1990 to 2019 using Joinpoint Regression Analysis

	Age Standardised Death rate (Global)		Age Standardised Death rate (India)		Age Standardised Death rate (South Asia)	
Segment	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)	Year	APC* (95% C.I.)
1	1990-1996	-2.16*(-4.43,-0.97)	1990-2005	-0.39(-0.84,0.17)	1990-2005	0.20(-0.14,0.55)
2	2004-2005	-0.55(-0.82,0.88)	2005-2010	3.24(-1.10-4.26)	2005-2010	3.30(-0.28,4.17)
3	2005-2013	1.61*(1.04,3.60)	2010-2013	5.49 (-0.07,6.42)	2010-2013	5.25*(0.19,6.05)
4	2013-2019	-0.68(-2.63-0.12)	2013-2019	-0.52(-1.36-0.24)	2013-2019	-0.35(-1.10,0.26)
AAPC*	1990-2019	-0.21* (-0.37, -0.09)	1990-2019	-0.80* (0.69, 0.89)	1990-2019	1.13*(1.04,1.21)

*Note: *, Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level; # Indicates that the AAPC Difference is significantly different from zero at the alpha = 0.05 level; APC, annual percentage change; AAPC, average annual percent change; CI, confidence interval.*

Table 3 shows the state-wise analysis of the ASIR and ASDR (per 100,000) in India for the year 2019, along with the AAPC from 1990 to 2019. Andhra Pradesh reported an incidence rate of 741.33 [CI:101.09-3727.33] and an AAPC of 0.63% (95% CI: 0.51-0.72). The death rate was 0.83 per 100,000 population (CI: 0.26-1.17) with an AAPC of -2.84% (95% CI: -3.74 to -1.49), indicating a significant decrease in mortality over time. This may be reflective of improved healthcare interventions and post-exposure prophylaxis. Delhi exhibited a decreasing trend in incidence with an AAPC of -0.62% (95% CI: -0.85 to -0.37) and an IRs of 1628.09 per 100,000 population (CI: 287.69-7986.45). The death rate was 2.83 per 100,000 population (CI: 0.3-4.26) with an AAPC of -6.02% (95% CI: -7.38 to -4.08), also showing a significant decline. These changes could be indicative of effective urban public health strategies and enhanced awareness and prevention measures. Goa demonstrated a marked increase in incidence with an AAPC of 2.51% (95% CI: 2.25-2.75) and IRs of 1165.22 (CI: 178.06-5438.07). The death rate was 0.72 (CI: 0.28-1.08) with an AAPC of 7.83% (95% CI: 5.71-9.15), indicating a significant increase in mortality. Karnataka had the highest reported incidence rate of 6875.84 per 100,000 population (CI: 752.91-24136.13) with an AAPC of 1.73% (95% CI: 1.62-1.85). The death rate was 1.41 per 100,000 population (CI: 0.3-1.99) with an AAPC of -1.73% (95% CI: -2.47 to -0.7), suggesting a significant decrease in mortality. This paradox may be attributed to a well-established system for dengue management, despite the high exposure rates. West Bengal showed an IRs of 1767.23 per 100,000 population (CI: 295.32-9742.07) while the death rate was 2.84 per 100,000 population (CI: 0.3-4.44) with an AAPC of 0.51% (95% CI: 0.07-0.86), indicating a slight but significant increase in mortality. The increase in mortality could be due to inadequate access to healthcare facilities or insufficient vaccination and control measures for the dengue vector population.

Age-standardized dengue incidence transition in India

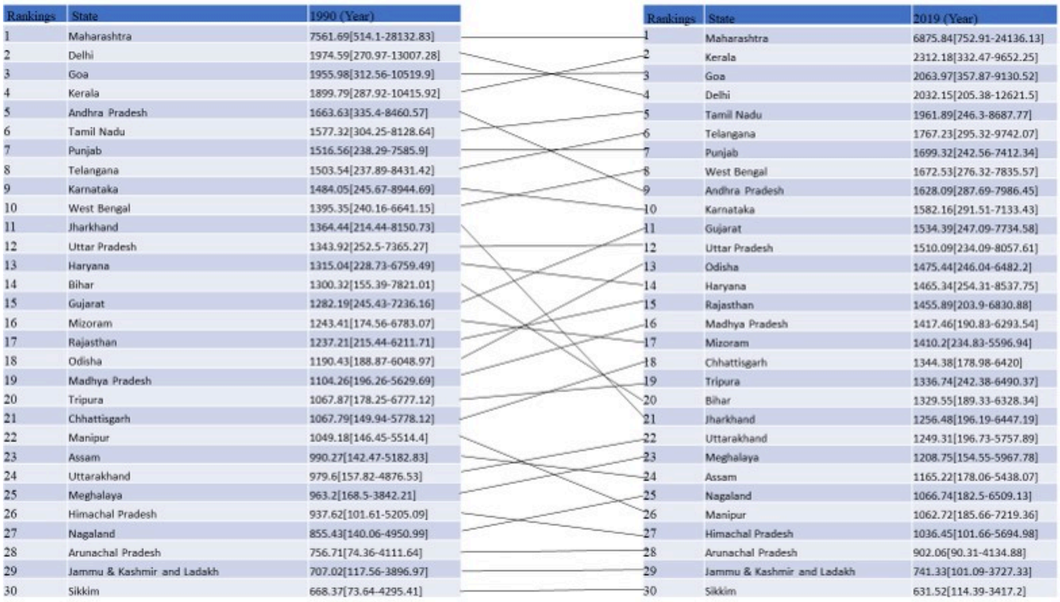
Figure 4a indicates the change in the state-wise rankings of ASIR of dengue in the period 1990-2019. States such as Maharashtra, Delhi goa, Kerala has remained the top states with the highest incidence of Dengue in country. While, states such as Sikkim, Jammu and Kashmir and Ladakh, Arunachal Pradesh have the lowest incidence rates.

Table 3: Age-standardized Incidence and death rates of dengue for India and its states in 2019 and their Average Annual Percentage Change (AAPC) from 1990 to 2019

State	Incidence		Death	
	Rates in 2019, 95% UI (per 100,000 Population)	AAPC (1990-2019)	Rates in 2019, 95% UI (per 100,000 Population)	AAPC (1990-2019)
Andhra Pradesh	741.33[101.09-3727.33]	0.63* (0.51,0.72)	0.83[0.26-1.17]	-2.84* (-3.74,-1.49)
Arunachal Pradesh	902.06[90.31-4134.88]	0.53* (0.4,0.63)	0.98[0.23-1.59]	2.41* (1.28,2.97)
Assam	1249.31[196.73-5757.89]	0.55* (0.33,0.74)	1.91[0.32-2.8]	5.24* (2.7,6.27)
Bihar	1036.45[101.66-5694.98]	0.9* (0.77,1.01)	0.53[0.27-0.84]	2.26* (1.63,2.6)
Chhattisgarh	1890.65[224.55-10394.75]	0.61* (0.48,0.75)	1.95[0.44-2.84]	-1.79* (-2.39,-1.05)
Delhi	1628.09[287.69-7986.45]	-0.62* (-0.85,-0.37)	2.83[0.3-4.26]	-6.02* (-7.38,-4.08)
Goa	1165.22[178.06-5438.07]	2.51* (2.25,2.75)	0.72[0.28-1.08]	7.83* (5.71,9.15)
Gujarat	2032.15[205.38-12621.5]	0.57* (0.43,0.72)	3.8[0.35-5.65]	2.32* (1.33,2.8)
Haryana	2063.97[357.87-9130.52]	1.88* (1.78,1.98)	0.48[0.26-0.98]	2.37* (2.17,2.52)
Himachal Pradesh	1465.34[254.31-8537.75]	0.34* (0.21,0.44)	2.43[0.28-3.5]	4.34* (2.5,5.13)
Jammu & Kashmir and Ladakh	1582.16[291.51-7133.43]	0.62* (0.51,0.72)	2.86[0.44-3.91]	1.14* (0.97,1.27)
Jharkhand	2312.18[332.47-9652.25]	-0.95* (-1.28,-0.69)	0.86[0.34-1.79]	1.67* (0.64,2.33)
Karnataka	6875.84[752.91-24136.13]	1.73* (1.62,1.85)	1.41[0.3-1.99]	-1.73* (-2.47,-0.7)
Kerala	1062.72[185.66-7219.36]	0.01(-0.08,0.1)	1.36[0.25-2.01]	1.48* (0.83,1.93)
Madhya Pradesh	1208.75[154.55-5967.78]	0.69* (0.52,0.82)	1.44[0.27-2.1]	2.61* (1.77,3.14)
Maharashtra	1410.2[234.83-5596.94]	1.3* (1.22,1.37)	0.25[0.14-0.8]	1.29* (1.18,1.41)
Manipur	1066.74[182.5-6509.13]	0.49* (0.39,0.57)	1.87[0.25-3.05]	0.64* (0.56,0.72)
Meghalaya	1475.44[246.04-6482.2]	0.89* (0.8,0.97)	0.32[0.18-0.87]	-3.47* (-4.63,-1.66)
Mizoram	1699.32[242.56-7412.34]	0.81* (0.56,1.04)	1.06[0.27-1.51]	6.75* (3.17,8.15)
Nagaland	1455.89[203.9-6830.88]	0.91*(0.81,1)	1.55[0.27-2.17]	-3.47* (-4.67,-1.62)
Odisha	631.52[114.39-3417.2]	0.22(-0.01,0.4)	0.51[0.21-0.92]	3.75* (1.66,4.54)
Other Union Territories	1961.89[246.3-8687.77]	1.77* (1.66,1.89)	1.31[0.57-2.12]	2.92* (2.45,3.25)
Punjab	1336.74[242.38-6490.37]	0.52* (0.34,0.66)	0.38[0.19-0.86]	1.52* (1.11,1.77)
Rajasthan	1672.53[276.32-7835.57]	1.22* (1.12,1.29)	0.85[0.29-1.31]	-1.9* (-2.58,-0.98)
Sikkim	1329.55[189.33-6328.34]	0.35* (0.19,0.48)	0.99[0.33-1.47]	3.1*(1.8,3.9)
Tamil Nadu	1344.38[178.98-6420]	0.27* (0.15,0.36)	1.62[0.25-2.38]	-2.94* (-3.65,-1.82)
Telangana	1256.48[196.19-6447.19]	0.87*(0.71,1)	0.66[0.23-1.1]	0.87*(0.71,1)
Tripura	1417.46[190.83-6293.54]	-0.24* (-0.46,-0.07)	1.56[0.26-2.2]	2.25* (1.08,2.83)

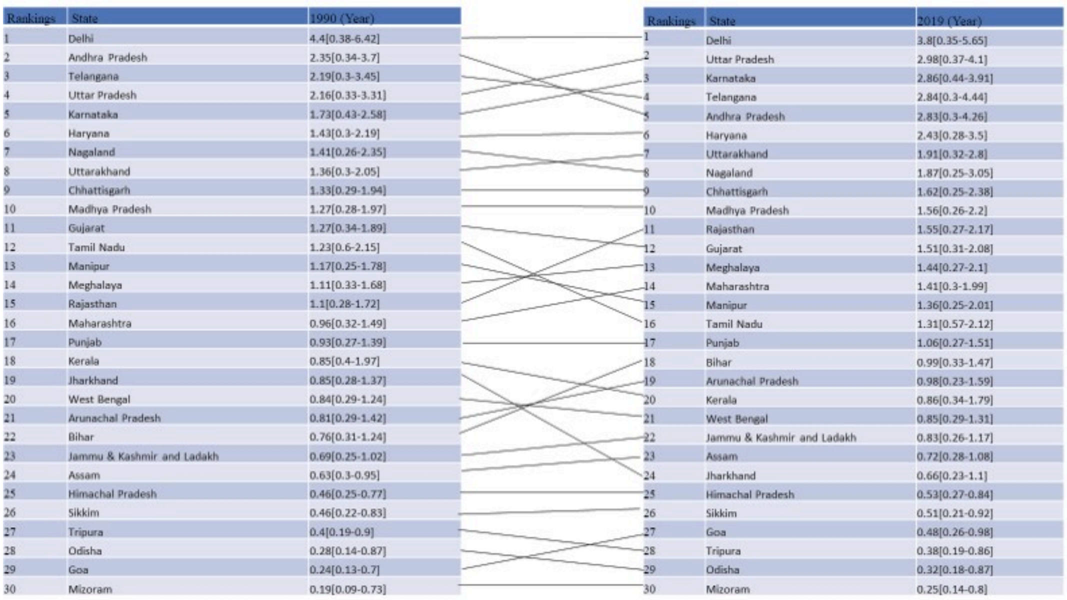
Uttar Pradesh	1510.09[234.09-8057.61]	1.07* (0.96,1.16)	2.98[0.37-4.1]	-0.82* (-1.26,-0.23)
Uttarakhand	1534.39[247.09-7734.58]	1.14* (1.03,1.23)	1.51[0.31-2.08]	-2.45* (-3.37,-1.39)
West Bengal	1767.23[295.32-9742.07]	0.06(-0.21,0.32)	2.84[0.3-4.44]	0.51* (0.07,0.86)

Maharashtra has the unexceptionally high IRs in the country with the incidence rate being thrice of Delhi which ranks second in the top 5 states with high dengue incidence. A majority of the states has witnessed an increase in the ASIR during 1990-2019. Those states are namely Kerala (412 points), Tamilnadu (385 points), Madhya Pradesh (313 points), Odisha (285 points), Chhattisgarh (277 points) and West Bengal (277 points). Very few states have shown a decline in the ASIR namely Maharashtra (1st rank, 686 points) and Jharkhand (11th rank, 108 points). Majority of the states have more or less remained at the same rank in highest to lowest state-wise dengue incidence.



Rankings	State	1990 (Year)	Rankings	State	2019 (Year)
1	Maharashtra	7561.69[514.1-28132.83]	1	Maharashtra	6875.84[752.91-24136.13]
2	Delhi	1974.59[270.97-13007.28]	2	Kerala	2312.18[332.47-9652.25]
3	Goa	1955.98[312.56-10519.9]	3	Goa	2063.97[357.87-9130.52]
4	Kerala	1899.79[287.92-10415.92]	4	Delhi	2032.15[205.38-12621.5]
5	Andhra Pradesh	1663.63[335.4-8460.57]	5	Tamil Nadu	1961.89[246.3-8687.77]
6	Tamil Nadu	1577.32[304.25-8128.64]	6	Telangana	1767.23[295.32-9742.07]
7	Punjab	1516.56[238.29-7585.9]	7	Punjab	1699.32[242.56-7412.34]
8	Telangana	1503.54[237.89-8431.42]	8	West Bengal	1672.53[276.32-7835.57]
9	Karnataka	1484.05[245.67-8944.69]	9	Andhra Pradesh	1628.09[287.69-7986.45]
10	West Bengal	1395.35[240.16-6641.15]	10	Karnataka	1582.16[291.51-7133.43]
11	Jharkhand	1364.44[214.44-8150.73]	11	Gujarat	1534.39[247.09-7734.58]
12	Uttar Pradesh	1343.92[252.5-7365.27]	12	Uttar Pradesh	1510.09[234.09-8057.61]
13	Haryana	1315.04[228.73-6759.49]	13	Odisha	1475.44[246.04-6482.2]
14	Bihar	1300.32[155.39-7821.01]	14	Haryana	1465.34[254.31-8537.75]
15	Gujarat	1282.19[245.43-7236.16]	15	Rajasthan	1455.89[203.9-6830.88]
16	Mizoram	1243.41[174.56-6783.07]	16	Madhya Pradesh	1417.46[190.83-6293.54]
17	Rajasthan	1237.21[215.44-6211.71]	17	Mizoram	1410.2[234.83-5596.94]
18	Odisha	1190.43[188.87-6048.97]	18	Chhattisgarh	1344.38[178.98-6420]
19	Madhya Pradesh	1104.26[196.26-5629.69]	19	Tripura	1336.74[242.38-6490.37]
20	Tripura	1067.87[178.25-6777.12]	20	Bihar	1329.55[189.33-6328.34]
21	Chhattisgarh	1067.79[149.94-5778.12]	21	Jharkhand	1256.48[196.19-6447.19]
22	Manipur	1049.18[146.45-5514.4]	22	Uttarakhand	1249.31[196.73-5757.89]
23	Assam	990.27[142.47-5182.83]	23	Meghalaya	1208.75[154.55-5967.78]
24	Uttarakhand	979.6[157.82-4876.53]	24	Assam	1165.22[178.06-5438.07]
25	Meghalaya	963.2[168.5-3842.21]	25	Nagaland	1066.74[182.5-6509.13]
26	Himachal Pradesh	937.62[101.61-5205.09]	26	Manipur	1062.72[185.66-7219.36]
27	Nagaland	855.43[140.06-4950.99]	27	Himachal Pradesh	1036.45[101.66-5694.98]
28	Arunachal Pradesh	756.71[74.36-4111.64]	28	Arunachal Pradesh	902.06[90.31-4134.88]
29	Jammu & Kashmir and Ladakh	707.02[117.56-3896.97]	29	Jammu & Kashmir and Ladakh	741.33[101.09-3727.33]
30	Sikkim	668.37[73.64-4295.41]	30	Sikkim	631.52[114.39-3417.2]

Figure 4a: Ranks of Age-Standardized dengue incidence rate of dengue per 100,000 population for all ages in 1990 and 2019 in India



Rankings	State	1990 (Year)	Rankings	State	2019 (Year)
1	Delhi	4.4[0.38-6.42]	1	Delhi	3.8[0.35-5.65]
2	Andhra Pradesh	2.35[0.34-3.7]	2	Uttar Pradesh	2.98[0.37-4.1]
3	Telangana	2.19[0.3-3.45]	3	Karnataka	2.86[0.44-3.91]
4	Uttar Pradesh	2.16[0.33-3.31]	4	Telangana	2.84[0.3-4.44]
5	Karnataka	1.73[0.43-2.58]	5	Andhra Pradesh	2.83[0.3-4.26]
6	Haryana	1.43[0.3-2.19]	6	Haryana	2.43[0.28-3.5]
7	Nagaland	1.41[0.26-2.35]	7	Uttarakhand	1.91[0.32-2.8]
8	Uttarakhand	1.36[0.3-2.05]	8	Nagaland	1.87[0.25-3.05]
9	Chhattisgarh	1.33[0.29-1.94]	9	Chhattisgarh	1.62[0.25-2.38]
10	Madhya Pradesh	1.27[0.28-1.97]	10	Madhya Pradesh	1.56[0.26-2.2]
11	Gujarat	1.27[0.34-1.89]	11	Rajasthan	1.55[0.27-2.17]
12	Tamil Nadu	1.23[0.6-2.15]	12	Gujarat	1.51[0.31-2.08]
13	Manipur	1.17[0.25-1.78]	13	Meghalaya	1.44[0.27-2.1]
14	Meghalaya	1.11[0.33-1.68]	14	Maharashtra	1.41[0.3-1.99]
15	Rajasthan	1.1[0.28-1.72]	15	Manipur	1.36[0.25-2.01]
16	Maharashtra	0.96[0.32-1.49]	16	Tamil Nadu	1.31[0.57-2.12]
17	Punjab	0.93[0.27-1.39]	17	Punjab	1.06[0.27-1.51]
18	Kerala	0.85[0.4-1.97]	18	Bihar	0.99[0.33-1.47]
19	Jharkhand	0.85[0.28-1.37]	19	Arunachal Pradesh	0.98[0.23-1.59]
20	West Bengal	0.84[0.29-1.24]	20	Kerala	0.86[0.34-1.79]
21	Arunachal Pradesh	0.81[0.29-1.42]	21	West Bengal	0.85[0.29-1.31]
22	Bihar	0.76[0.31-1.24]	22	Jammu & Kashmir and Ladakh	0.83[0.26-1.17]
23	Jammu & Kashmir and Ladakh	0.69[0.25-1.02]	23	Assam	0.72[0.28-1.08]
24	Assam	0.63[0.3-0.95]	24	Jharkhand	0.66[0.23-1.1]
25	Himachal Pradesh	0.46[0.25-0.77]	25	Himachal Pradesh	0.53[0.27-0.84]
26	Sikkim	0.46[0.22-0.83]	26	Sikkim	0.51[0.21-0.92]
27	Tripura	0.4[0.19-0.9]	27	Goa	0.48[0.26-0.98]
28	Odisha	0.28[0.14-0.87]	28	Tripura	0.38[0.19-0.86]
29	Goa	0.24[0.13-0.7]	29	Odisha	0.32[0.18-0.87]
30	Mizoram	0.19[0.09-0.73]	30	Mizoram	0.25[0.14-0.8]

Figure 4b: Ranks of Age-Standardized deaths rate due to dengue per 100,000 populations for all ages in 1990 and 2019 in India

Age-standardized dengue mortality transition in India

Figure 4b indicates the changes in positioning of states by highest to lowest age-standardized dengue mortality among all ages over the period 1990 - 2019. Over the span of three decades, Delhi has remained on the top with the highest age-standardized death rate (4.4 in 1990 and 3.8 in 2019) and ASDR has increased in the period 1990-2019. It was followed by states such as Andhra Pradesh, Telangana, Uttar Pradesh which have remained in top 5 states with highest ASDR over the period. States such as Mizoram, followed by Goa, Odisha, Tripura and Mizoram have the lowest ASDR due to dengue in the country in the period 1990-2019. Despite Maharashtra having the unexceptionally high incidence of dengue in the country, it lies at the 17th place in 1990 in deaths due to dengue and remained at 15th rank in 2019. Except Delhi, all of the states have witnessed an increase in the ASDR of dengue in the period. Jharkhand has witnessed a major slip in the descending state wise ASDR ranking. In simpler terms, Jharkhand stood at 19th rank in overall age standardized deaths due to dengue in 1990 while it was ranked at 24th position in 2019. Tamilnadu has also shifted from 12th rank to 16th rank respectively. States such as Haryana, Chhattisgarh, Madhya Pradesh, Himachal Pradesh and Sikkim have remained at the same position in year 1990 and 2019. In contrast, states such as Rajasthan, Bihar and Maharashtra have moved upwards in state wise ranking of ASDR due to dengue.

Figure 5 shows the state wise dengue incidence and mortality in the year 1990 and 2019 per 100,000 population in India.

(A)

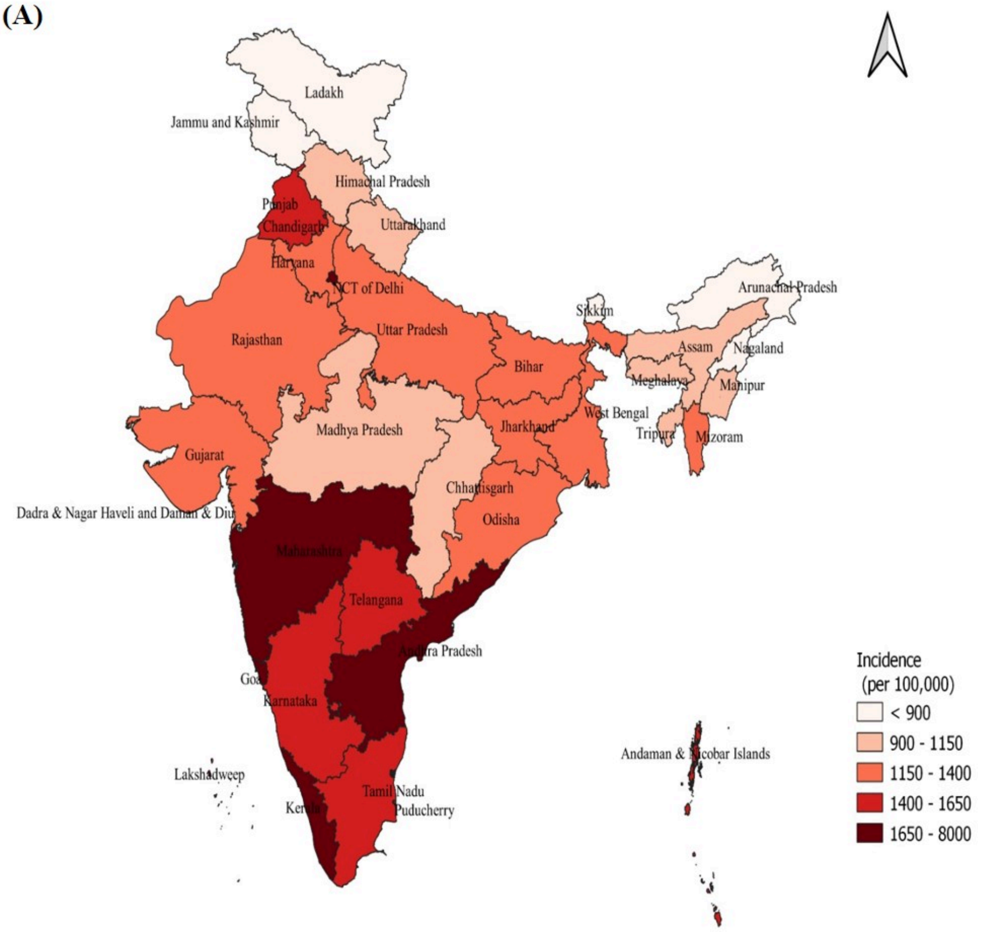


Figure 5: Incidence and Mortality of dengue from 1990 to 2019 per 100,000 population in India. A. Incidence of dengue per 100,000 population in 1990.

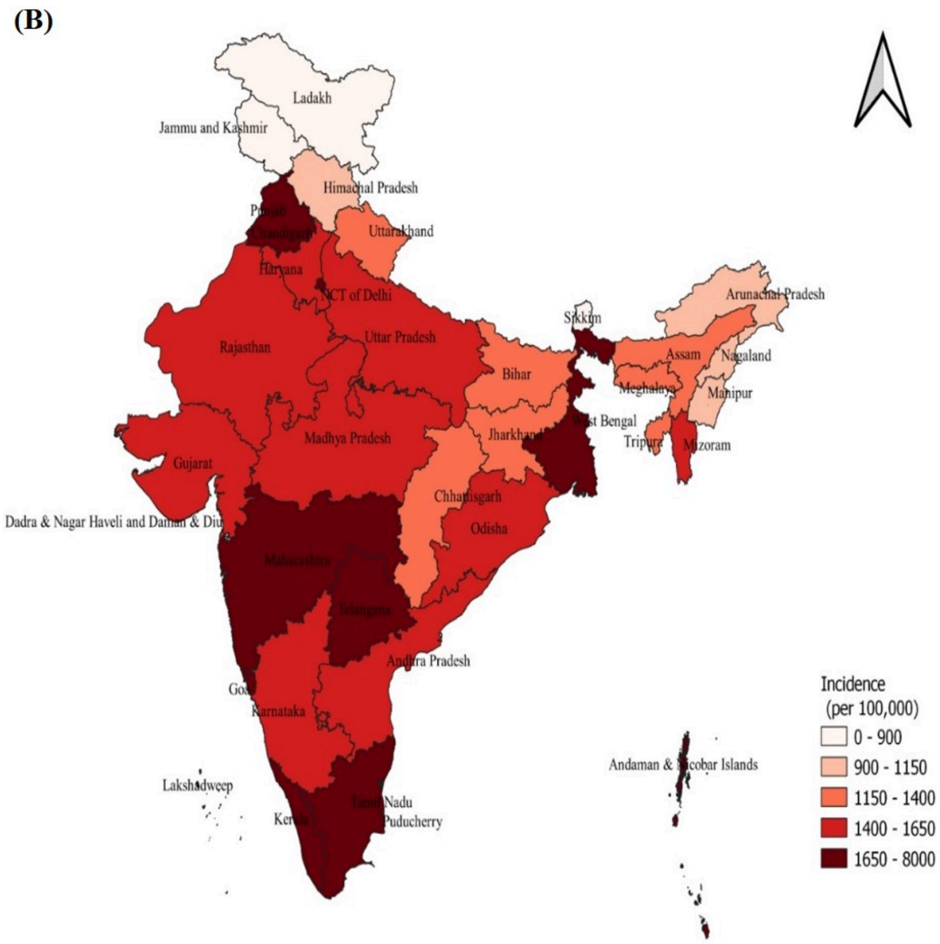


Figure 5: Incidence and Mortality of dengue from 1990 to 2019 per 100,000 population in India. B. Incidence of dengue per 100,000 population in 2019.

Discussion

The findings of the study highlight significant variations in the trends of dengue incidence and mortality rates across India, as well as in comparison to global and South Asian levels. While India exhibits higher age-standardized incidence and death rates relative to the global and South Asian averages, the patterns of change over time present a more complex scenario. The trends observed in India can be compared and contrasted with findings from other dengue-endemic regions. For example, a research study emphasized the economic impact and the burden of disease caused by dengue in Southeast Asia, indicating the importance of effective public health interventions in reducing both incidence and mortality [13]. A study noted an increase in dengue incidence globally, a trend also observed in India, although at a comparatively modest rate [14]. Specifically, the ASIR of dengue in India shows a modest AAPC of 0.14% (95% CI: 0.12 to 0.15), which is lower than the AAPCs observed globally and in South Asia. This indicates a relatively slower increase in the incidence of dengue in India compared to these broader regions. This resurgence is partly attributed to urbanization and globalization [2] and due to factors like travel and trade [15]. The COVID-19 pandemic, due to health service saturation, may have diverted attention and resources from dengue control and management, potentially leading to underreporting of cases and reduced effectiveness of dengue surveillance and intervention efforts. The strain on healthcare systems worldwide could have impacted the routine diagnosis, reporting, and management of dengue, potentially altering observed trends in incidence and mortality. The number of months suitable for A. aegypti dengue transmission in India grew by 169% annually to 56 months between 1951–1960 and 2012–21 [16]. On the other hand, the age-standardized death rate (ASDR) from dengue in India is decreasing, with an AAPC of -0.80% (95% CI: 0.69 to 0.89). This trend contrasts with South Asia, where an increase in the dengue mortality rate is noted, with an

AAPC of 1.13% (95% CI: 1.04 to 1.21). Sang et al. noted the role of socio-economic development in shaping dengue transmission dynamics, a factor that is also significant in the Indian context, where urbanization and socio-economic disparities are prominent [17]. An increased diagnostic capabilities could potentially influence observed trends in dengue-related mortality Additionally, the necessity of international collaboration and shared learning, particularly in the development and implementation of vaccines and antiviral drugs has been emphasized [18]. While India has made significant strides in dengue control, insights from global research can guide further improvements. Recently, India has advanced in dengue diagnostic capabilities thus improving the detection rates of dengue and expanding the capacity to identify milder and asymptomatic cases. Such advancements likely contribute to the observed reduction in mortality rates, as the increase in diagnosed cases, including less severe ones, affects the overall mortality calculations.

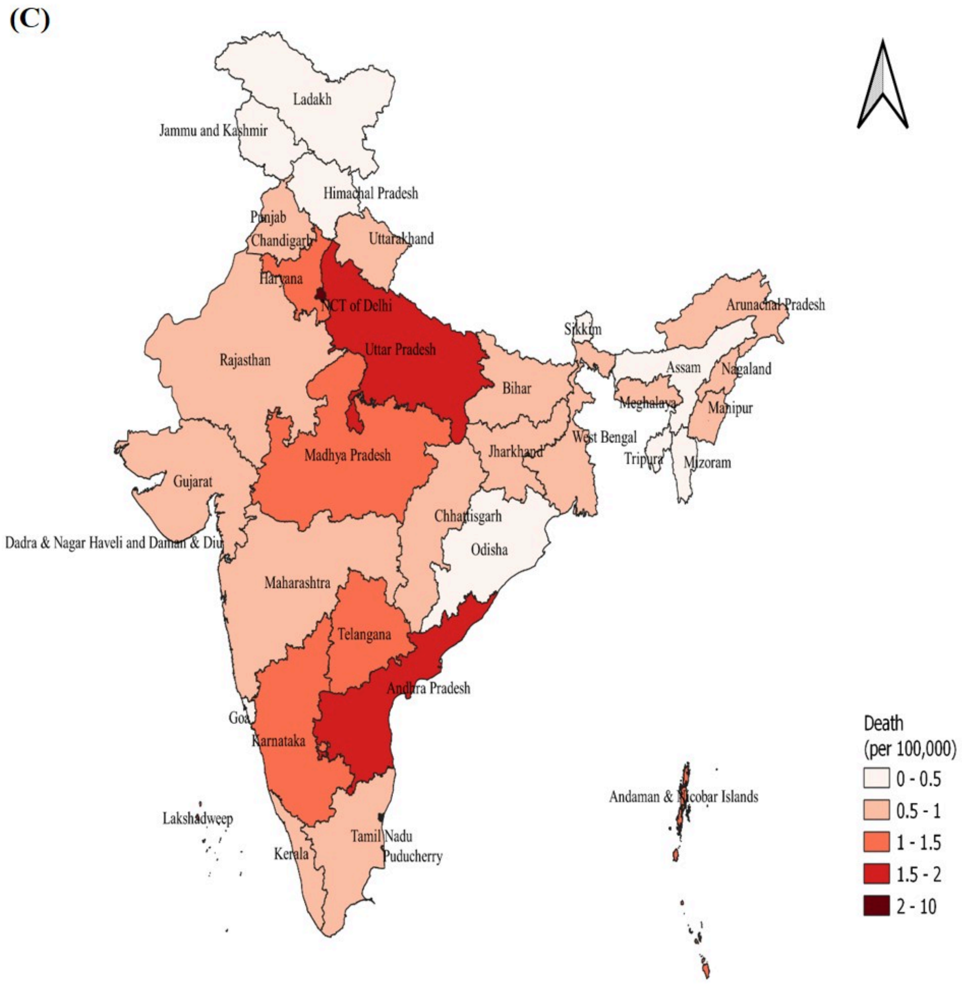


Figure 5: Incidence and Mortality of dengue from 1990 to 2019 per 100,000 population in India. C. Mortality of dengue per 100,000 population in 1990.

The study also uncovers regional disparities within India itself. While some states like Delhi, Jharkhand, and Tripura are experiencing a decline in dengue incidence, others such as Assam, Goa, Mizoram, Himachal Pradesh, and Odisha are witnessing an increase in mortality rates. The rising trend of dengue incidence is not unique[9, 19, 20] and emphasizes the need for regional cooperation and shared learning in dengue management. Shared climatic and environmental drivers of dengue transmission in the Asian context [21] and changes in population immunity and virus serotypes can influence disease trends [22]. Literature shows that West Bengal, Uttar Pradesh, Punjab, Haryana, Delhi, Gujarat, Kerala, Karnataka and Tamil Nadu are the high dengue burden states [8]. Consistent with our study findings, significant geographical variability has been observed [1, 23]highlighting the necessity of localized strategies, a principle mirrored in the Indian context where different states exhibit varying trends in dengue incidence and mortality.

Findings on the impact of climate variables on dengue transmission [24] are particularly relevant for India, given its diverse climatic conditions and the influence of monsoon patterns on vector populations. The significant direct and indirect costs associated with the disease [13] and considering the regional variations in dengue trends, as indicated by the differing AAPCs across Indian states, region-specific strategies are essential. For states like Delhi, Jharkhand, and Tripura, where incidence rates are declining, the focus should be on maintaining and strengthening existing control measures, ensuring sustainability. In contrast, states like Assam, Goa, Mizoram, Himachal Pradesh, and Odisha, experiencing increased mortality rates, may require intensified vector control efforts, improved clinical management of cases, and enhanced public health awareness campaigns. Moreover, in states where mortality rates are declining, such as Delhi, Meghalaya, Nagaland, Tamil Nadu, and Andhra Pradesh, it's vital to analyze and replicate successful strategies. This could involve community-based initiatives, effective case management protocols, and robust surveillance systems.

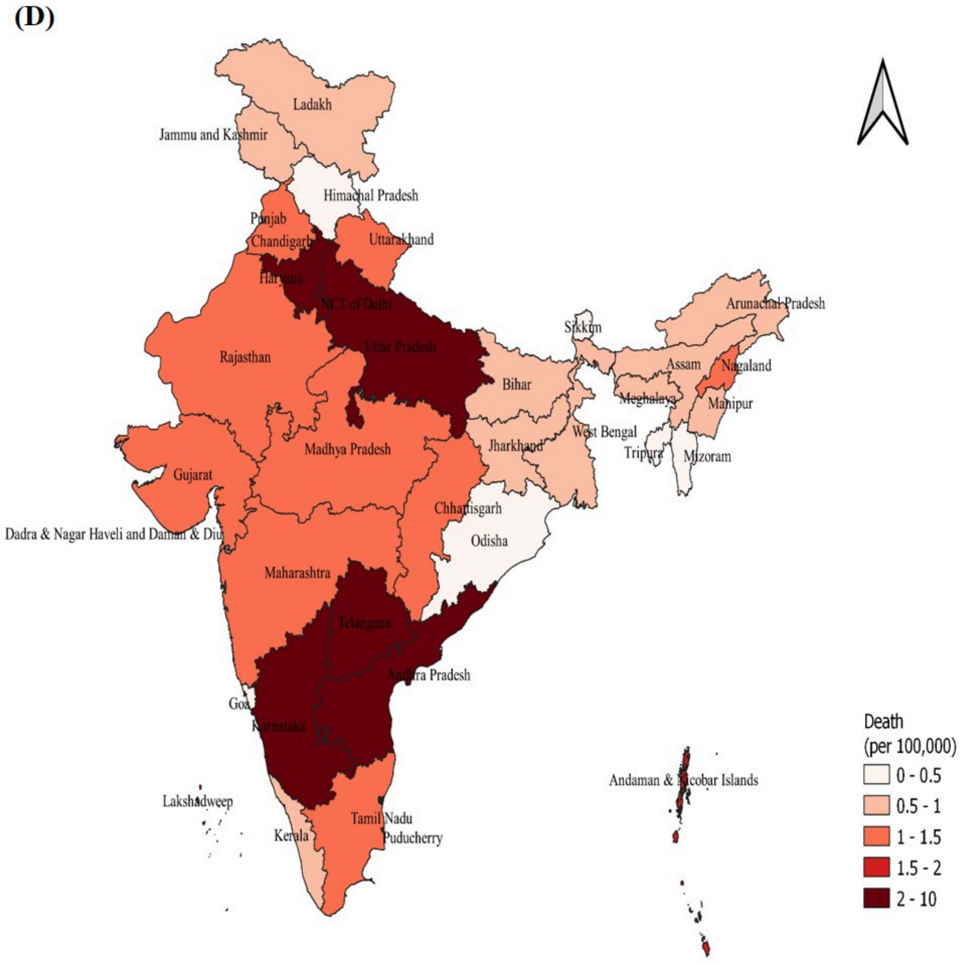


Figure 5: Incidence and Mortality of dengue from 1990 to 2019 per 100,000 population in India. D. Mortality of dengue per 100,000 population in 2019.

In India, particularly, the variation in trends across different states underscores the need for region-specific strategies in dengue control and prevention efforts. The differing trends in incidence and mortality rates highlight the importance of tailored public health interventions and resource allocation to effectively combat dengue in diverse regional contexts. Furthermore, a study on global dengue mortality rates over time reflects the variable impact of dengue worldwide, underscoring the importance of context-specific strategies, a principle that is highly applicable in the diverse Indian context [25]. This similarity suggests common regional challenges, such as urbanization and climate change, impacting dengue transmission [20]. Gubler highlighted the dengue as a public health problem, emphasizing the need to rebuild and strengthen public health infrastructures to manage these epidemic vector-borne diseases effectively [2]. This resurgence is part of a broader

Trend of emerging and re-emerging infectious diseases that pose a significant challenge to global health systems [2]. The climatic factors contribute to the spatial and temporal variations in dengue risk, necessitating region-specific approaches in disease forecasting models [4]. Moreover, routine dengue diagnosis in endemic regions has been advocated as a critical measure to reduce the burden of the disease [26]. Accurate diagnosis can lead to early treatment and prevention of disease spread, particularly in regions where dengue often presents with symptoms similar to other endemic diseases like malaria.

At the national level, India's approach to dengue control has primarily been focused on vector control, public awareness campaigns, and strengthening healthcare systems to manage dengue cases effectively. The National Vector Borne Disease Control Programme plays a pivotal role in coordinating and implementing vector control strategies across the country. These strategies include source reduction, larvicide, and fogging, alongside surveillance of vector densities. However, as highlighted in the study, the effectiveness of these interventions can vary regionally, necessitating a more tailored approach. The integration of dengue control programs within the broader framework of the National Health Mission (NHM) allows for a more holistic approach to health and well-being, aligning with the SDG goal of reducing mortality through improving healthcare services. The NHM emphasizes strengthening healthcare infrastructure and capacity building at the grassroots level, which is crucial for early dengue detection and management. The economic burden of dengue in India highlights the need for affordable dengue management measures [27]. An Indian study highlighted the epidemiological characteristics of dengue in different Indian states and reported the heterogeneity in dengue transmission across states [6]. This finding aligns with the current study, emphasizing the need for region-specific strategies [6].

The SDG 3.3 aims to combat infectious diseases like dengue, and the goal of reducing mortality aligns with the observed trends in dengue mortality in India. The reduction in mortality rates in certain regions indicates progress towards these SDGs. However, the increasing incidence in other regions highlights the need for sustained and targeted efforts. It's imperative that dengue control strategies contribute to the broader health system strengthening, enhancing resilience against not only dengue but other vector-borne diseases as well. The reliance on epidemiological surveillance systems for vector-borne diseases, including dengue, as a primary source of incidence rates introduces potential variability in our findings. Changes in case reporting within these information systems, driven by advancements in diagnostic capabilities, public health initiatives, or changes in reporting protocols, could impact the accuracy of observed trends in dengue incidence and mortality. It's plausible that enhancements in surveillance and reporting practices over recent years have led to an increase in the detection and reporting of dengue cases, thereby influencing the perceived trends. This consideration underscores the importance of interpreting our findings within the context of evolving epidemiological surveillance systems and reporting practices, acknowledging that such improvements may contribute to a more accurate, albeit possibly inflated, depiction of dengue incidence rates.

Conclusion

The findings from the study on dengue incidence and mortality trends in India provide a basis for refining regional and national dengue control programs. While India shows a modest increase in dengue incidence, it has successfully achieved a reduction in mortality rates, contrasting with the trends in other South Asian regions. These findings underscore the complexities of dengue control, influenced by factors such as urbanization, globalization, climatic changes, and socio-economic development. The study's revelation of significant regional disparities within India further emphasizes the necessity for tailored public health strategies that are adaptable to local epidemiological and environmental conditions. Aligning these programs with the SDGs, particularly the goal of reducing mortality, is crucial. The progress observed in certain Indian states demonstrates the potential for significant improvements in dengue control, but the regional disparities highlight the need for tailored strategies. Comparisons with global literature further emphasize the importance of adaptive, evidence-based approaches and international collaboration in combating dengue. Therefore, continuous monitoring, evaluation, and adaptation of dengue control strategies are essential for achieving both national health objectives and global health goals.

In light of the findings, several key recommendations emerge for enhancing dengue control efforts. Firstly, it is imperative to develop and implement region-specific strategies. This approach should account intensifying vector control, improving clinical management, and boosting public health awareness in regions with rising dengue rates. Investing in robust monitoring systems and conducting epidemiological studies will enable early detection of outbreaks and inform timely interventions. In our analysis of the regional variations in the effectiveness of dengue control strategies, it is imperative to acknowledge the significant role of community engagement. The degree of community involvement in preventive measures, particularly in eliminating larval breeding sites, stands out as a crucial determinant of these strategies' success. Empirical evidence underscores the positive correlation between active community participation and the reduction in dengue transmission risks. Therefore, we emphasize the importance of fostering community awareness and action as integral to combating dengue, highlighting how variations in this engagement can influence the effectiveness of control measures across different regions. Furthermore, integrating dengue control programs within broader public health initiatives, particularly under the National Health Mission, will ensure a holistic approach to health and well-being. Community engagement and education are vital for raising awareness about dengue prevention and control, enhancing community participation in proactive measures. Additionally, healthcare infrastructure development, especially in high-burden states, is essential for effective dengue management, including enhancing diagnostic and treatment capacities. Economic analyses to understand the direct and indirect costs associated with dengue are necessary for efficient resource allocation, with a focus on cost-effective strategies, particularly in resource-limited settings. These recommendations, collectively, aim to strengthen India's fight against dengue, contributing to global efforts in reducing the burden of infectious diseases.

Abbreviations

AAPC: Average Annual Percent Change

APC: Annual percentage change

ASDR: Age-standardized death rate

ASIR: Age-standardized incidence rate

EIP: Extrinsic incubation period

GHDx: Global Health Data Exchange

IHME: Institute for Health Metrics and Evaluation

NHM: National Health Mission

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Ethical Considerations: Not applicable

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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.

Clinical Trial: Not applicable

Consent for publication: Note applicable

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