Original Article

STATISTICAL ANALYSIS ON CERVICAL CANCER SCREENING, INCIDENCE AND MORTALITY TRENDS IN INDIA USING GBD/OGD/ICMR-NCRP DATABASE-AN AMBISPECTIVE STUDY

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ABSTRACT

Objectives:

To examine recent state-wise trends in cervical cancer screening, incidence, and mortality in India and to forecast future patterns using regression analysis.

Methods:

A retrospective ecological study was conducted using secondary data from national and global databases for 2019–2023. State-level screening coverage, incidence, and mortality rates were analysed. Descriptive statistics, Pearson correlation, and linear regression models were applied. Projections for 2024–2033 were generated using regression coefficients. Model fit was assessed using the coefficient of determination (R^2).

Results:

Marked inter-state variation was observed in screening coverage, incidence, and mortality. Lower screening rates were generally associated with higher mortality. Several states demonstrated increasing incidence trends, while mortality was stable or gradually declining in regions with better screening infrastructure. Positive correlations were identified between development indicators and reported incidence, likely reflecting improved detection and reporting. Forecasts suggest that regional disparities may persist if screening expansion remains limited. Most models showed strong explanatory power ($R^2 > 0.80$, $p < 0.05$).

Conclusion:

Despite gradual national improvements, significant regional disparities in cervical cancer burden remain. Strengthening organized screening programs, ensuring timely follow-up care, and expanding HPV vaccination coverage are critical to reducing preventable cervical cancer in India.

Keywords: Cervical Cancer; Mass Screening; Incidence; Mortality; Regression Analysis.

HIGHLIGHTS

• Significant inter-state disparities exist in cervical cancer incidence and mortality in India.
• Lower screening coverage is associated with higher mortality rates.
• Regression models demonstrate strong predictive performance for short-term forecasting.
• Regional inequalities may persist without strengthening organized screening and HPV vaccination.

INTRODUCTION

Cancer remains a major global public health concern and continues to be one of the leading causes of morbidity and mortality worldwide. Among malignancies affecting women, cervical cancer is unique in that it is largely preventable; however, it still contributes substantially to global mortality, particularly in low- and middle-income countries where access to screening and treatment services is limited [1,2]. In India, cervical cancer constitutes a significant proportion of female cancers, with disease outcomes strongly influenced by disparities in socioeconomic status, awareness, and healthcare accessibility [5].

Cervical cancer arises from malignant transformation of epithelial cells in the cervix, most commonly within the transformation zone. Histologically, it is primarily categorized into squamous cell carcinoma and adenocarcinoma, of which squamous cell carcinoma accounts for the majority of cases [3]. Persistent infection with high-risk human papillomavirus (HPV), especially types 16 and 18, is the principal etiological factor [4]. The disease typically progresses through identifiable precancerous stages, collectively termed cervical intraepithelial neoplasia, which may evolve into invasive cancer over a prolonged period of 10–20 years if left untreated [9,10]. This extended preclinical phase provides a critical opportunity for early detection and intervention.

Globally, cervical cancer remains among the most frequently diagnosed cancers in women, with the majority of deaths occurring in resource-limited settings, reflecting inequalities in screening coverage and treatment access [1,6]. In India, substantial regional variation exists in incidence and mortality patterns, with rural populations experiencing a disproportionately higher burden due to limited awareness and low participation in screening programs [5,6]. Age-specific trends indicate that incidence increases after 30 years and peaks between 45 and 60 years.

Several biological and behavioural determinants contribute to cervical cancer risk, including persistent HPV infection, early onset of sexual activity, multiple sexual partners, prolonged oral contraceptive use, smoking, immunosuppression, and coexisting infections [4,7]. In addition, inadequate knowledge, poor health-seeking behaviour, and insufficient screening infrastructure frequently result in delayed diagnosis and advanced disease presentation [8].

Screening is widely recognized as the most effective strategy for cervical cancer prevention. Commonly used methods include cytological screening via the Papanicolaou test, visual inspection with acetic acid (VIA), and HPV DNA testing, each differing in sensitivity, cost, and feasibility [11]. In India, population-based screening programs primarily employ VIA and Pap smear techniques because of their affordability and operational feasibility in public health

settings [12]. Despite these initiatives, screening coverage remains suboptimal, and many cases are detected at advanced stages, adversely affecting survival outcomes [5,6].

Reliable epidemiological data are essential for monitoring disease patterns and guiding public health policy. Large-scale databases such as the Global Burden of Disease study and national cancer registry systems provide standardized information on incidence, mortality, and temporal trends, thereby supporting evidence-based decision-making and research [13].

Primary prevention through HPV vaccination represents a major advancement in cervical cancer control. Vaccines targeting oncogenic HPV types have demonstrated high effectiveness, particularly when administered before viral exposure [15,16]. In India, the introduction of the indigenous quadrivalent vaccine Cervavac® is expected to improve accessibility and strengthen national prevention strategies [17]. Nevertheless, vaccination complements rather than replaces screening, as current vaccines do not protect against all carcinogenic HPV types [18].

Although numerous studies describe the epidemiology of cervical cancer, limited research has focused on forecasting future disease trends using robust statistical modelling approaches. Regression-based analyses of historical data can generate projections of incidence, mortality, and screening coverage, thereby assisting policymakers in planning targeted interventions and optimizing resource allocation [14]. Therefore, the present study applies regression modelling to recent national and global datasets to estimate future cervical cancer trends in India and provide evidence to support improved prevention and control strategies.

METHODOLOGY

Study Design and Setting

This study was designed as an ambispective, population-based ecological analysis combining retrospective assessment of secondary data with prospective statistical prediction of cervical cancer incidence and mortality trends across India. The analysis covered all states and union territories, with data aggregated at the state level to enable geographic comparisons.

Study Period

The retrospective analysis included data from 2019 to 2023. Future trends were projected for a 10-year period from 2024 to 2033.

Data Sources

Secondary data were obtained from publicly accessible national and international databases. These included the Global Burden of Disease (GBD) Study for cervical cancer incidence, mortality, and age-standardized rates; the ICMR National Cancer Registry Programme (NCRP) for population-based cancer registry statistics; and the Government of India Online Government Data (OGD) platform for screening coverage and health system indicators related to cancer control programs. Only data pertaining to the female population were included.

Study Variables

The dependent variables analysed were cervical cancer screening rate (%), incidence rate (per 100,000 women), and mortality rate (per 100,000 women). Records with incomplete information, duplicate entries across databases, or non-standardized estimates were excluded from analysis.

Data Extraction and Management

Relevant data were extracted and compiled in Microsoft Excel spreadsheets and cross-validated across data sources to ensure consistency. Variables were coded and formatted prior to statistical analysis.

Statistical Analysis

Descriptive statistics including mean and median values were calculated to summarize state-wise and year-wise trends. Graphical representations, including line graphs and bar charts, were generated using Microsoft Excel and R software.

Correlation between socioeconomic development indicators and cervical cancer incidence and mortality rates was assessed using Pearson correlation analysis. Incidence and mortality rates were calculated using the formula:

$$\text{Rate} = \frac{\text{Number of cases or deaths}}{\text{Female population}} \times 100{,}000$$

Temporal trends were evaluated using linear regression models, with calendar year as the independent variable. The regression equation used was:

$$Y = a + bX$$

where Y represents the dependent variable, X represents time, a is the intercept, and b is the regression coefficient indicating annual change.

Prediction of Future Trends

Forecasts for incidence and mortality from 2024–2033 were generated using regression coefficients derived from observed data between 2019 and 2023. Predictions were calculated separately for each state using R statistical software.

Model Validation

Model performance was assessed using the coefficient of determination (R^2). Residual analysis was conducted to verify assumptions of linear regression. All statistical tests were two-sided, and p values < 0.05 were considered statistically significant.

Software

Data management, descriptive analysis, and graphical visualization were performed using Microsoft Excel. Regression modelling, prediction, and advanced visualization were conducted using R software (version 4.5.2).

Outcome Measures

Primary outcomes included projected incidence and mortality rates of cervical cancer across Indian states and identification of high-risk regions based on predicted disease burden.

Limitations

The study relied on secondary datasets, which may contain reporting inconsistencies. The retrospective observation period was limited to five years, and projections assumed continuation of linear trends, which may not fully capture future epidemiological changes.

RESULTS

Descriptive Analysis of Cervical Cancer Indicators

Descriptive statistics demonstrated substantial inter-state variation in cervical cancer screening, incidence, and mortality across India. Mean incidence rates fluctuated moderately during the study period, whereas median values indicated relative stability in central tendencies across states. Mortality rates exhibited comparable patterns; however, states with lower screening coverage consistently showed higher mortality levels. Graphical representations generated using statistical software illustrated year-wise patterns, revealing increase in incidence and mortality in the regions (figure 1).

State-wise Trend Analysis

Linear regression analysis conducted for each state and union territory showed heterogeneous temporal patterns. Majority of the states demonstrated increase in incidence trends, whereas others displayed stable or slightly increasing trajectories. Mortality trends also increase slowly in states with relatively improper screening programs, while states with limited screening infrastructure showed minimal improvement. The coefficient of determination (R^2) values indicated moderate to strong model fit for most states, suggesting that calendar year explained a substantial proportion of temporal variation in incidence, and mortality rates (figure 2,3).

Correlation Between Socioeconomic Development and Disease Burden

Correlation analysis examining associations between Human Development Index (HDI) and cervical cancer indicators revealed statistically significant positive relationships in several states. Higher-HDI regions tended to report higher incidence and mortality rates, possibly reflecting improved diagnostic capacity and reporting systems rather than true increases in disease burden. These findings highlight the complex interaction between socioeconomic development, healthcare access, and disease detection patterns (figure 4).

Projection of Future Trends

Forecasting based on regression coefficients derived from 2019–2023 data indicated that incidence rates are likely to increase in states where screening coverage is not improving. Mortality rates are projected to decrease slowly, particularly in regions expanding organized screening programs. Scatter plots comparing observed and predicted values showed strong concordance, suggesting reliable short-term projections. Model outputs demonstrated

statistically significant regression coefficients and high explanatory power (e.g., R^2 values approaching unity in certain state models), supporting the validity of projections.

Projected estimates for selected states suggest a steady increase in predicted values over the forecast period when existing trends are extrapolated, underscoring the potential persistence of regional disparities if interventions are not intensified (figure 5).

Model Validation

Validation analyses confirmed the robustness of regression models. High R^2 values indicated acceptable explanatory power, and residual distributions appeared random, supporting regression assumptions. Most regression coefficients were statistically significant ($p < 0.05$), indicating that linear models were appropriate for short-term epidemiological forecasting at the population level.

DISCUSSION

This ambispective ecological analysis provides a comprehensive state-wise evaluation of cervical cancer incidence and mortality trends across India using nationally representative datasets. The findings reveal persistent geographic disparities and highlight the importance of screening programs and socioeconomic development in reducing disease burden.

The observed gradual increase in incidence during the study period may reflect improvements in case detection following the implementation of national cancer control initiatives and integration of screening services into primary healthcare. Nevertheless, the relatively modest pace of change indicates continuing gaps in program reach, public awareness, and accessibility.

The inverse relationship between screening coverage and mortality emphasizes the critical role of early detection in preventing advanced disease and reducing deaths. States with higher development indices generally demonstrated better screening uptake and lower mortality, underscoring the influence of healthcare infrastructure, education, and economic resources on cancer outcomes.

Forecast projections suggest that although certain regions may experience stabilization or decline, others could face continued increases in incidence and mortality if current trends persist. This indicates that passive screening strategies alone may be insufficient to substantially reduce disease burden. Strengthening organized population-based screening, expanding vaccination coverage, and addressing regional inequities are essential to accelerate progress.

From a public health and surveillance perspective, these findings reinforce the need for continuous monitoring, evaluation of screening interventions, and data-driven policymaking. The use of multiple national databases enhances analytical reliability; however, reliance on secondary data sources and the assumption of linear trend continuation represent inherent limitations that should be considered when interpreting projections.

CONCLUSION:

This ambispective study, utilizing data from the Global Burden of Disease (GBD), Office of the Registrar General & Census Commissioner of India (OGD), and the Indian Council of Medical Research–National Cancer Registry Programme (ICMR-NCRP), provides a comprehensive statistical assessment of cervical cancer screening, incidence, and mortality trends in India. The integration of multiple national and global databases strengthens the reliability of findings and allows for a robust evaluation of both historical patterns and emerging trends across regions and time periods.

The analysis indicates that, while there has been a gradual decline in the overall incidence and mortality of cervical cancer at the national level, the disease continues to pose a significant public health burden in India. Wide inter-state and regional disparities persist, with higher incidence and mortality rates observed in several low- and middle-socio-demographic index (SDI) states. These variations reflect unequal access to healthcare services, differences in awareness levels, screening coverage, socioeconomic conditions, and health system capacity. Despite medical advances and policy initiatives, cervical cancer remains a leading cause of cancer-related morbidity and mortality among Indian women.

Low uptake of Pap smear, VIA/VILI, and HPV testing continues to delay early detection, leading to diagnosis at advanced stages and consequently higher mortality rates. Statistical trend analysis highlights a strong inverse relationship between effective screening coverage and cervical cancer mortality, underscoring the critical role of early detection in improving survival outcomes.

Mortality trend analysis further demonstrates that reductions in death rates have not kept pace with declines in incidence, suggesting gaps in timely diagnosis, referral, and treatment. This indicates that screening alone is insufficient without strong follow-up systems, accessible treatment facilities, and continuity of care. The findings also emphasize the growing importance of HPV vaccination as a preventive strategy, which, if scaled up effectively, could substantially reduce future incidence and mortality.

In conclusion, this ambispective statistical analysis highlights that cervical cancer in India is largely preventable, yet remains inadequately controlled due to disparities in screening, prevention, and healthcare access. Strengthening population-based screening programs, expanding HPV vaccination coverage, improving cancer registry data quality, and addressing regional inequities are essential for sustained reduction in cervical cancer burden. Evidence generated from this study can inform policymakers and public health authorities in designing targeted, data-driven interventions aligned with national cancer control strategies and the goal of cervical cancer elimination in India.

ETHICAL CONSIDERATIONS:

This study utilized publicly available secondary datasets with no individual -level identifiers. Institutional ethical approval was not required.

CONFLICT OF INTEREST:

The authors declare no conflicts of interest.

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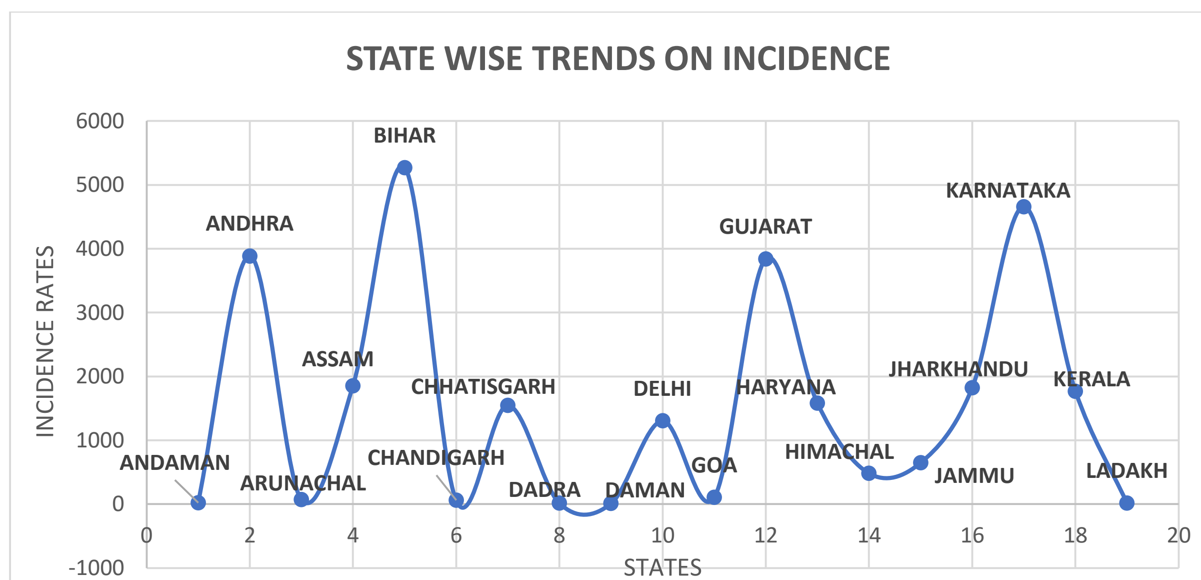
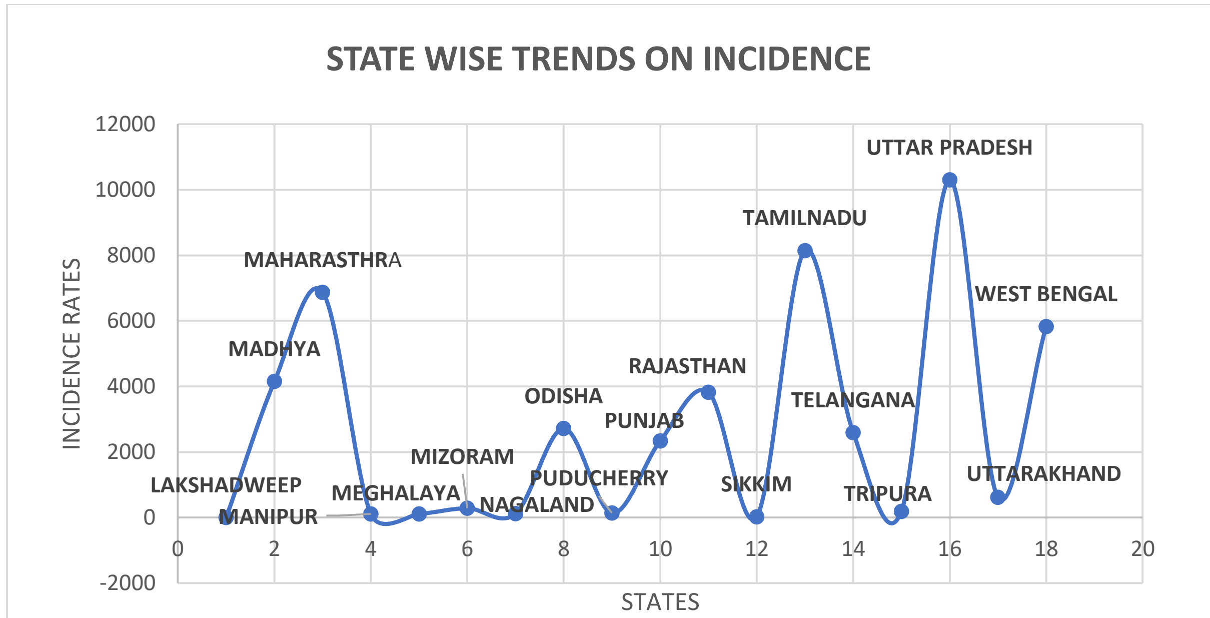
Sl.No	State / UT	2019	2020	2021	2022	2023	mean
1	Andaman	21	23	23	25	25	23.4
2	Andhra Pra	3713	3799	3886	3973	4063	3886.8
3	Arunachal	68	71	74	75	78	73.2
4	Assam	1754	1802	1851	1900	1952	1851.8
5	Bihar	4941	5073	5207	5348	5489	5271.8
6	Chandigar	58	58	60	62	63	60.2
7	Chhattisga	1467	1507	1545	1584	1626	1545.8
8	Dadra & N	15	15	15	16	17	15.6
9	Daman	9	9	9	10	12	9.8
10	Delhi	1217	1259	1303	1348	1394	1304.2
11	Goa	101	104	106	107	109	105.4
12	Gujarat	3637	3738	3840	3943	4048	3841.2
13	Haryana	1486	1536	1580	1630	1678	1582
14	Himachal	461	474	483	495	506	483.8
15	Jammu &	612	632	648	666	684	648.4
16	Jharkhand	1723	1770	1821	1874	1926	1822.8
17	Karnataka	4419	4536	4657	4776	4900	4657.6
18	Kerala	1699	1734	1771	1804	1840	1769.6
19	Ladakh (U	15	16	16	16	17	16
20	Lakshadwe	4	4	4	4	6	4.4
21	Madhya Pr	3934	4042	4151	4264	4378	4153.8
22	Maharasht	6545	6708	6872	7037	7207	6873.8
23	Manipur	101	103	107	112	117	108
24	Meghalaya	109	111	113	117	123	114.6
25	Mizoram	134	139	143	147	153	286.4
26	Nagaland	114	116	121	124	127	120.4
27	Odisha (Or	2595	2656	2717	2778	2844	2718
28	Puducherr	128	133	138	143	148	138
29	Punjab	2223	2280	2339	2399	2459	2340
30	Rajasthan	3620	3721	3822	3927	4034	3824.8
31	Sikkim	26	26	27	29	29	27.4
32	Tamil Nad	7768	7958	8144	8337	8534	8148.2
33	Telangana	2466	2532	2595	2665	2731	2597.8
34	Tripura	185	191	194	199	204	194.6
35	Uttar Prad	9793	10046	10301	10559	10825	10304.8
36	Uttarakha	594	608	624	639	656	624.2
37	West Beng	5534	5679	5823	5971	6119	5825.2
	India – Tot	73289	75209	77130	79103	81121	
	MEDIAN	16					

STATE/UN	2019	2020	2021	2022	2023	mean	LAKSHADV	5	5	5	5	5	5
ANDHAMN	9	10	10	11	11	10.2	MADHYA F	1731	1778	1826	1876	1926	1827.4
ANDHRA P	1014	1672	1710	1748	1788	1586.4	MAHARAS	2880	2952	3024	3096	3171	3024.6
ARUNACH.	30	31	33	33	34	32.2	MANIPUR	44	45	47	49	51	47.2
ASSAM	772	793	814	836	859	814.8	MEGALAY/	48	49	50	51	54	50.4
BIHAR	2174	2232	2291	2353	2415	2293	MIZORAM	59	61	63	65	67	63
CHANDIG/	26	26	26	27	28	26.6	NAGALANI	50	51	53	55	56	53
CHATTISG/	645	663	680	697	715	680	ODISHA	1142	1169	1195	1222	1251	1195.8
DADRA AN	7	7	7	7	7	7	PUDUCHEI	56	59	61	63	65	60.8
DAMAN	11	12	12	12	12	11.8	PUNJAB	978	1003	1029	1056	1082	1029.6
DELHI	535	554	573	593	613	573.6	RAJASTHAI	1593	1637	1682	1728	1775	1683
GOA	44	46	47	47	48	46.4	SIKKIM	11	11	11	13	13	11.8
GUJARAT	1600	1645	1690	1735	1781	1690.2	TAMIL NAI	3418	3502	3584	3669	3755	3585.6
HARYANA	654	676	695	717	738	696	TELUNGAI	1085	1114	1142	1173	1202	1143.2
HIMACHAI	203	209	213	218	223	213.2	TRIPURA	81	84	85	88	90	85.6
JAMMU AI	269	278	285	293	301	285.2	UTTAR PR/	4309	4420	4532	4646	4763	4534
JHARKHAN	758	779	801	825	847	802	UTTARAN(	261	268	275	281	289	274.8
KARNATAK	1944	1996	2049	2101	2156	2049.2	WEST BEN	2435	2499	2562	2627	2692	2563
KERALA	748	763	779	794	810	778.8	TOTAL	32246	33095	33938	34806	35691	
LADAKH	7	7	7	7	7	7	MEDIAN						7

Figure 1: Descriptive analysis of cervical cancer indicators

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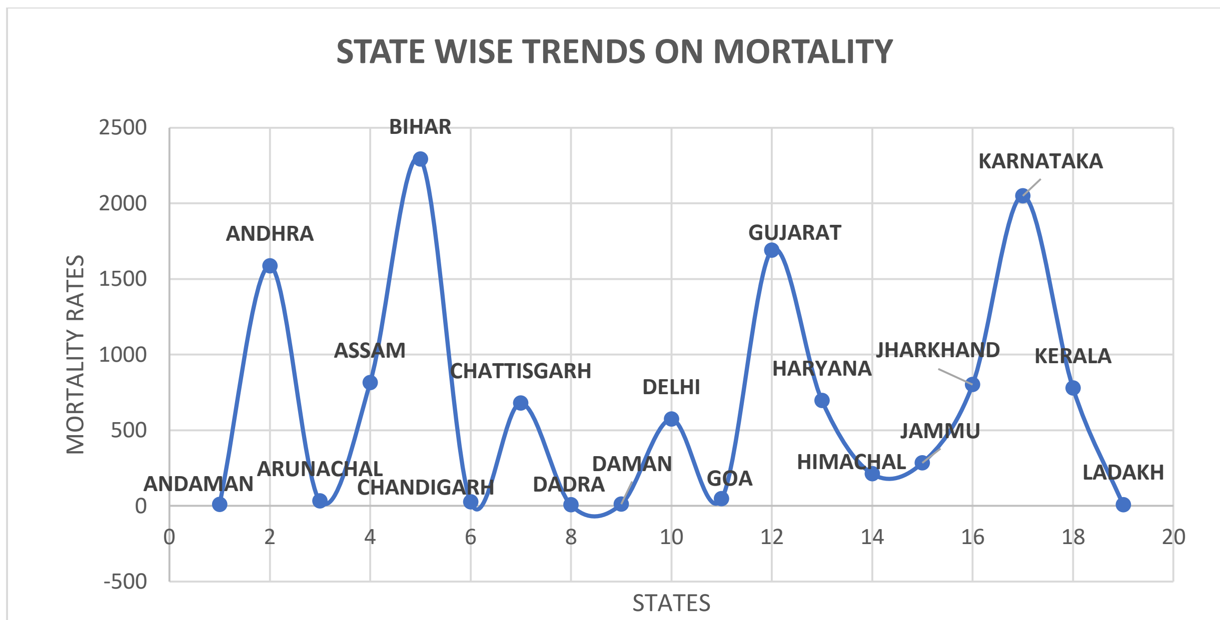
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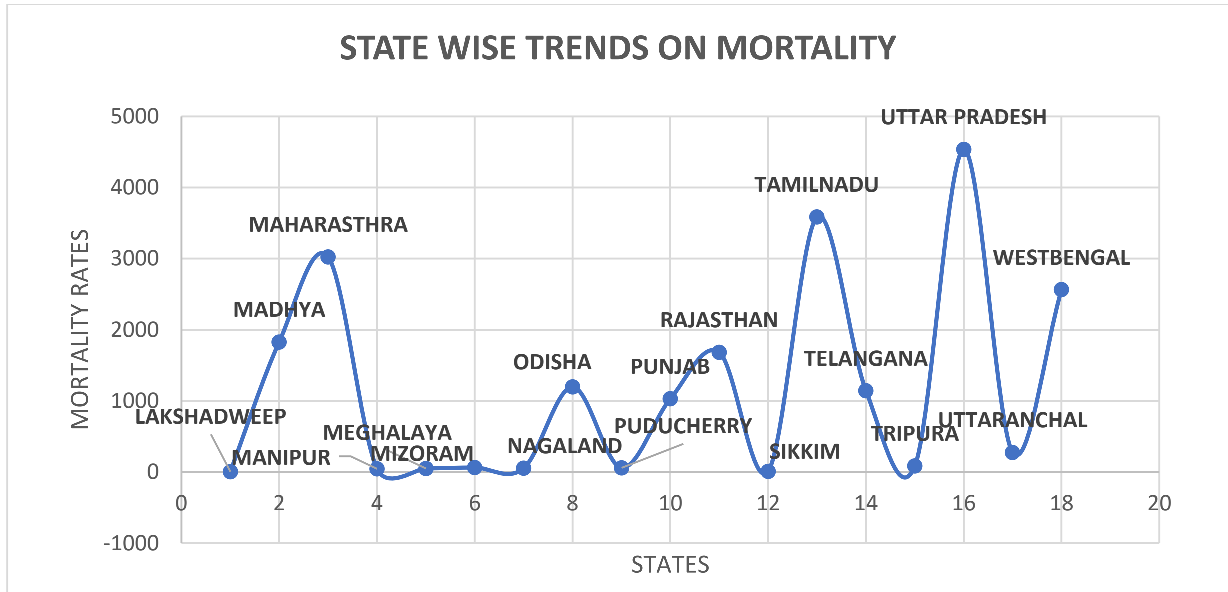


Figure 2: Trend analysis of cervical cancer indicators.

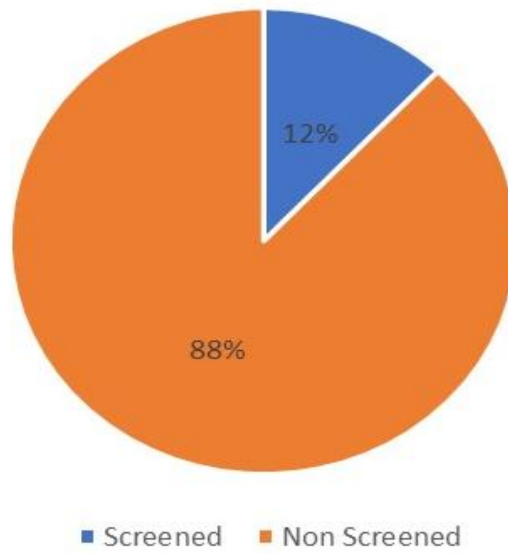
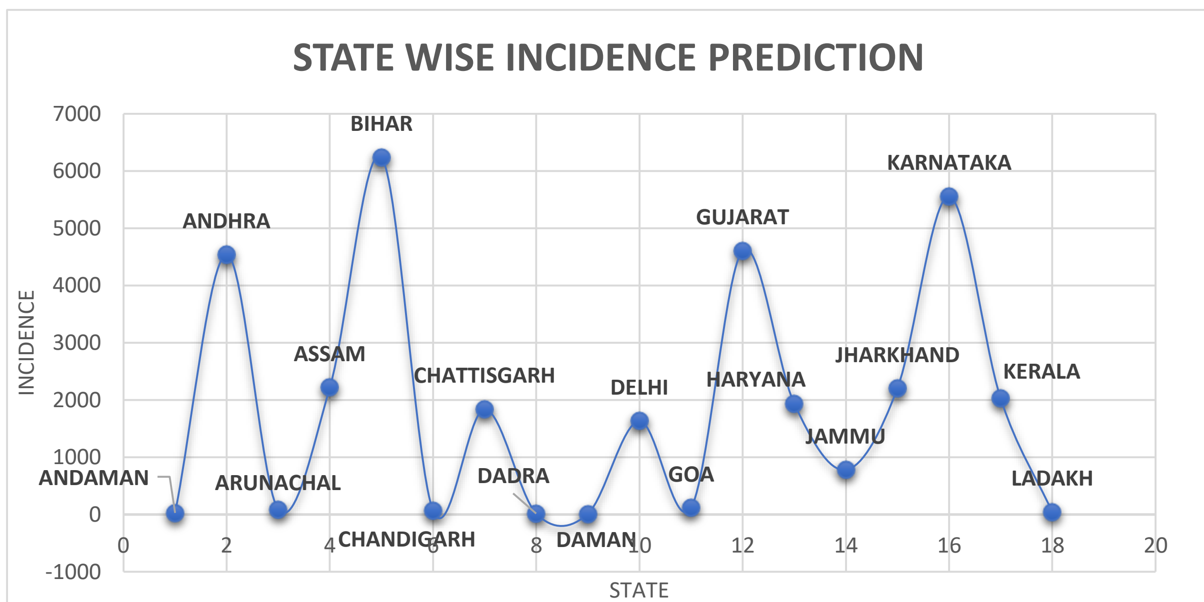


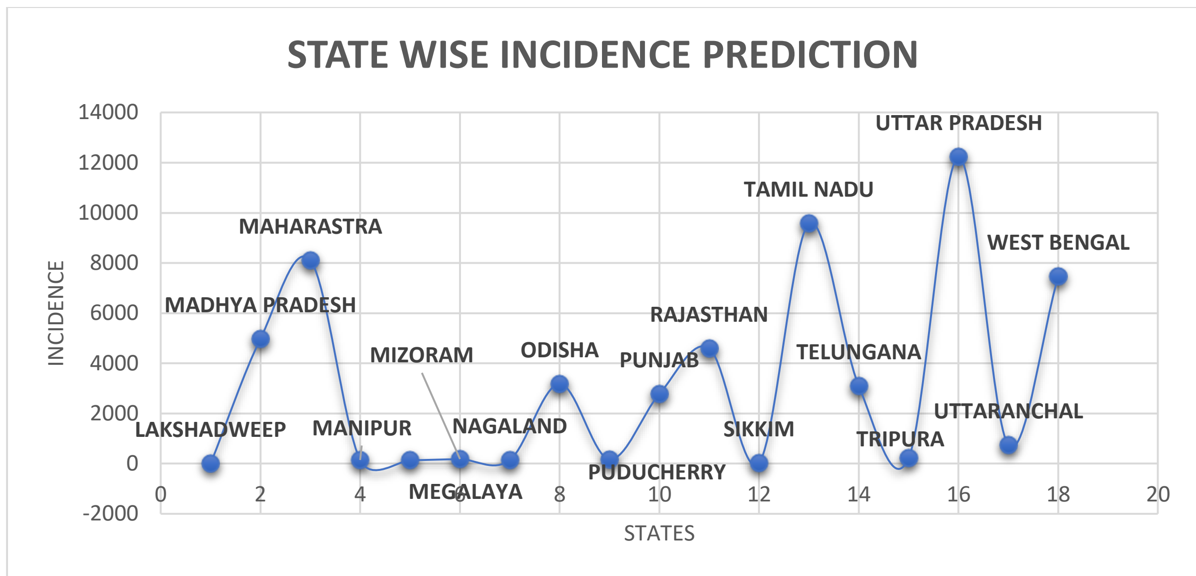
Figure 3: Screening trends

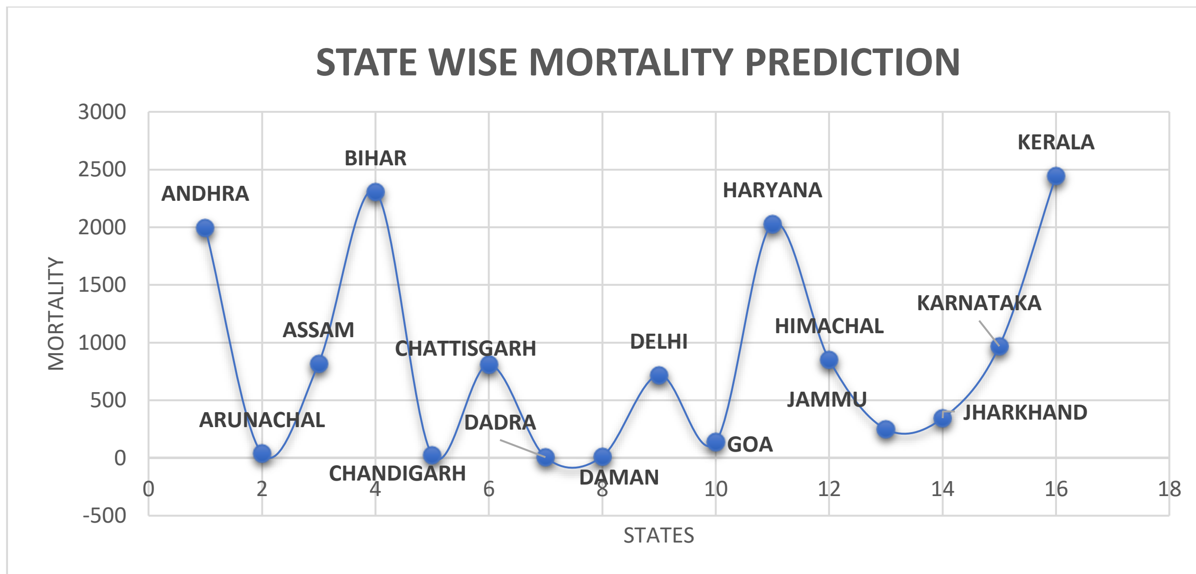
Year	HDI	INCIDENC	FEMALE PO	INCIDENCE RATE
2019	0.645	73289	671679248	10.911
2020	0.645	75209	678442228	11.018
2021	0.633	77130	684279793	11.271
2022	0.644	79103	689891756	11.466
2023	0.685	81121	696186332	11.652
CORRELAT	0.62126	POSITIVE		

YEAR	HDI	MORTALIT	MORTALITY RATE
2019	0.645	32246	4.8
2020	0.645	33095	4.878
2021	0.633	33938	4.959
2022	0.644	34806	5.045
2023	0.685	35691	5.079
CORRELAT	0.529948	POSITIVE	

Figure 4: Correlation between HDI and cervical cancer indicators.







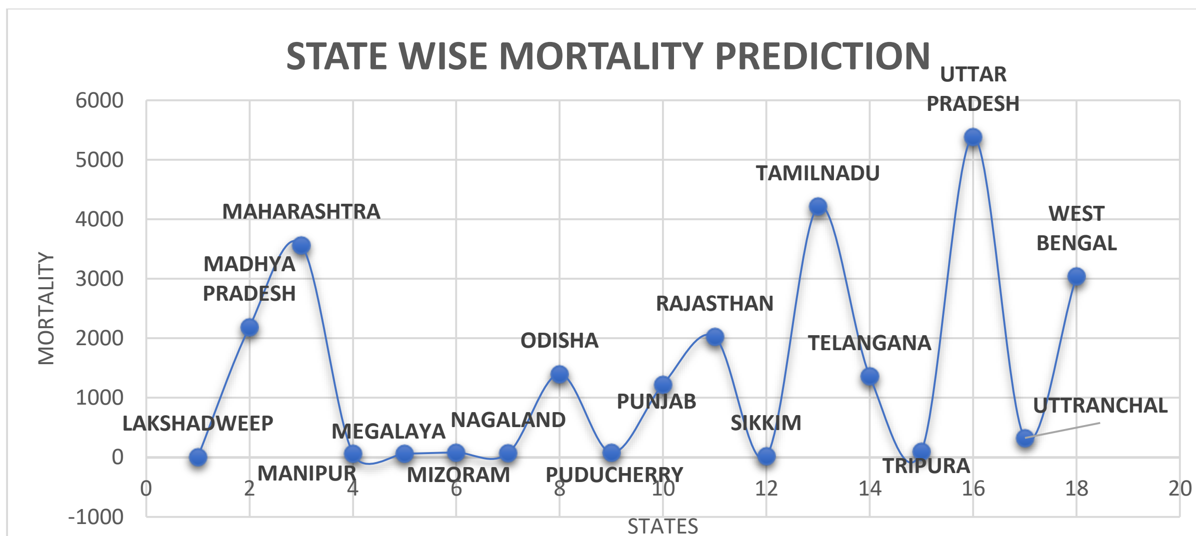


Figure 5: Projection of future trends

STUDY PERIOD	STATES	INCIDENCE R^2	INCIDENCE P	MORTALITY R^2	MORTALITY P
2019-2023	ANDAMAN AND NICOBAR	0.8571	0.01539	0.85	0.05132
2019-2023	ANDHRA PRADESH	0.9999	$2.384e^{-0}$	0.9999	$4.796e^{-07}$
2019-2023	ARUNACHAL PRADESH	0.9728	0.001245	0.9012	0.008754
2019-2023	ASSAM	0.9997	$1.32e^{-06}$	-0.1636	0.5555
2019-2023	BIHAR	0.9997	$1.683e^{-06}$	-0.1612	0.5526
2019-2023	CHANDIGARH	0.9231	0.005986	-0.1444	0.5323
2019-2023	CHATTISGARH	0.9997	$1.941e^{-06}$	0.9998	$6.444e^{-07}$
2019-2023	DADRA AND NAGAR HAVELI	0.7083	0.04666	NA	NA
2019-2023	DAMAN	0.6275	0.068	0.3333	0.1817
2019-2023	DELHI	0.9996	$2.212e^{-06}$	0.9998	$1.06e^{-06}$
2019-2023	GOA	0.9606	0.002178	-0.3333	0.9905
2019-2023	GUJARAT	0.9999	$1.776e^{-07}$	1	$3.677e^{-08}$
2019-2023	HARYANA	0.9996	$2.574e-^{06}$	0.9994	$3.848e^{-06}$
2019-2023	HIMACHAL PRADESH	0.9971	$4.342e^{-05}$	0.9961	$6.658e^{-05}$
2019-2023	JAMMU AND KASHMIR	0.9988	$1.1143e^{05}$	0.9985	$1.592e^{-05}$
2019-2023	JHARKHAND	0.9993	$4.631e^{06}$	0.9994	$4.437e^{-06}$
2019-2023	KARNATAKA	0.9999	$3.53e^{07}$	0.9999	$4.022e^{-07}$
2019-2023	KERALA	0.9997	$1.441e^{06}$	0.9998	$5.921e^{07}$
2019-2023	LADAKH	0.9703	0.009959	NA	NA
2019-2023	LAKSHADWEEP	0.3333	0.1817	NA	NA
2019-2023	MADHYA PRADESH	0.9998	$7.998e^{-07}$	0.9997	$1.214e^{-06}$
2019-2023	MAHARASHTRA	0.9703	0.009959	0.9999	$2.396e^{-07}$

2019-2023	MANIPUR	0.9703	0.009959	0.9837	0.0005737
2019-2023	MEGALAYA	0.9177	0.006627	0.8994	0.009007
2019-2023	MIZORAM	0.9925	0.00018	1	$2.2e^{-16}$
2019-2023	NAGALAND	0.9818	0.0006798	0.9795	0.0008136
2019-2023	ODISHA	0.9997	$1.78e^{-06}$	0.9995	$2.99e^{-06}$
2019-2023	PUDUCHERRY	1	$<2.2e^{-16}$	0.9891	0.0003157
2019-2023	PUNJAB	0.9999	$5.007e^{-07}$	0.9998	$8.707e^{-07}$
2019-2023	RAJASTHAN	0.9998	$1.021e^{-06}$	0.9998	$9.328e^{-07}$
2019-2023	SIKKIM	0.8406	0.01822	0.6667	0.05767
2019-2023	TAMIL NADU	0.9999	$4.993e^{07}$	0.9999	$2.598e^{-07}$
2019-2023	TELUNGANA	0.9997	$1.434e^{07}$	0.9997	$1.397e^{-06}$
2019-2023	TRIPURA	0.99	0.0002765	0.9783	0.0008843
2019-2023	UTTAR PRADESH	0.9999	$4.0053e^{-07}$	0.9999	$5.028e^{-07}$
2019-2023	UTTRANCHAL	0.9987	$1.256e^{-05}$	0.998	$2.388e^{-05}$
2019-2023	WEST BENGAL	0.9703	0.009959	0.9999	$1.026e^{-07}$

Table 1: Regression coefficient and Pearson correlation analysis of incidence and mortality of states in India.