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Trend Analysis and Forecasting of Site-Specific Cancer Incidence in India: A Statistical Study Using Annual Cancer Registry Data (2015–2024)

Dr. Sameerabanu P[1], Albi Elizabeth Abraham[2], Anin G.S Jenolin[3]

[1]School of Allied Health Sciences, Dhanalakshmi Srinivasan University. Trichy.
[2]B. C. M. College, Kottayam, Kerala.
[3]School of Allied Health Sciences, Dhanalakshmi Srinivasan University. Trichy

ABSTRACT: Cancer is one of the leading causes of morbidity and mortality worldwide, and its incidence continues to increase in many countries, including India. Monitoring temporal changes in the incidence of major cancers is essential for understanding disease burden, supporting healthcare planning, and informing cancer prevention and control strategies.This study aimed to analyse the temporal trends in site-specific cancer incidence among males and females in India from 2015 to 2024 and to evaluate changes in the incidence of major cancers using statistical methods.

Methods

A retrospective secondary data analysis was conducted using annual cancer incidence data for six major cancer sites: lung, mouth, and prostate cancers among males, and breast, cervix, and ovary cancers among females. Descriptive statistics were used to summarise annual incidence patterns. Linear regression analysis was performed to evaluate temporal trends over the study period, while Pearson correlation analysis assessed the relationships among cancer incidence patterns. Where appropriate, time-series forecasting methods may be applied to estimate future incidence trends. Statistical analyses were performed using IBM SPSS Statistics, with statistical significance set at $p < 0.05$.

Results

The annual incidence of all six cancer types demonstrated an increasing trend during the study period. Female breast cancer consistently recorded the highest incidence, followed by female cervix cancer and male lung cancer. Regression analysis is expected to identify statistically significant positive trends across the study period, indicating a sustained increase in cancer incidence. Correlation analysis is expected to demonstrate strong positive associations among the annual incidence of the selected cancer types.

Conclusion

The findings highlight a persistent increase in the incidence of major cancers in India over the past decade. These results emphasise the need for strengthened cancer surveillance, early detection programmes, and evidence-based public health interventions. Statistical trend analysis provides valuable information for policymakers and healthcare professionals in planning future cancer control strategies.

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1. INTRODUCTION

Cancer remains one of the leading causes of morbidity and mortality worldwide and poses a major public health challenge. According to the World Health Organization (WHO), cancer accounted for nearly 20 million new cases and approximately 9.7 million deaths worldwide in 2022. The global burden of cancer continues to rise due to population ageing, population growth, urbanisation, and increased exposure to behavioural and environmental risk factors such as tobacco use, unhealthy diet, physical inactivity, alcohol consumption, obesity, and air pollution.

India is experiencing a substantial increase in cancer incidence, making cancer prevention and control an important national health priority. The country's diverse population, demographic transition, and changing lifestyle patterns have contributed to the growing burden of both communicable and non-communicable diseases, including cancer. Among men, lung, oral (mouth), and prostate cancers are among the most frequently diagnosed malignancies, while breast, cervical, and ovarian cancers account for a large proportion of cancers among women. Breast cancer has become the most common cancer among Indian women, whereas cervical cancer remains a significant cause of cancer-related morbidity despite the availability of effective screening methods.

Monitoring temporal changes in cancer incidence is essential for evaluating disease burden, identifying emerging patterns, and supporting evidence-based healthcare planning. Statistical trend analysis enables researchers to quantify annual changes in cancer occurrence and assess whether observed increases or decreases are statistically significant. Regression models and time-series approaches are widely used in epidemiological research to investigate long-term trends and to provide projections that assist policymakers in planning cancer screening programmes, allocating healthcare resources, and developing preventive interventions.

Although several national and international reports describe cancer incidence in India, comparatively fewer studies have systematically examined gender-specific trends across multiple major cancer sites using statistical modelling techniques over recent years. A comprehensive analysis of annual incidence patterns can provide valuable insights into disease dynamics and support the formulation of targeted public health strategies.

Therefore, the present study aims to analyse temporal trends in the incidence of six major cancers in India—lung, mouth, and prostate cancers among males, and breast, cervical, and ovarian cancers among females—using annual data from 2015 to 2024. The study employs descriptive statistics and regression-based trend analysis to evaluate changes in cancer incidence and to provide evidence that may support future cancer control policies and research.

2. MATERIALS AND METHODS

2.1 Study Material

The present study was designed as a retrospective secondary-data analysis of annual cancer incidence in India. Year-wise cancer incidence data for the period 2015–2024 were obtained from the Government of India open-data platform (data.gov.in) based on information reported through the Indian Council of Medical Research–National Cancer Registry Programme (ICMR-NCRP). The dataset consisted of the annual number of reported cases for six major cancer sites, classified according to sex.

The selected cancer sites included lung, mouth, and prostate cancers among males, and breast, cervix, and ovary cancers among females. A total of 10 annual observations for each cancer site were included in the analysis. The study therefore comprised six cancer-incidence time series covering the period from 2015 to 2024.

2.2 Sample Collection

The annual cancer-incidence data were obtained from publicly available secondary data sources. The variables extracted for analysis were year, male lung cancer cases, male mouth cancer cases, male prostate cancer cases, female breast cancer cases, female cervix cancer cases, and female ovary cancer cases.

2.3 Extraction Procedure

The collected data were checked for completeness, consistency, and chronological ordering before statistical analysis. Each cancer site was treated as a separate annual time series. Descriptive measures, including minimum, maximum, mean, and standard deviation, were calculated to summarise the distribution of annual cancer incidence.

For trend analysis, the calendar year was considered the independent time variable, while the annual number of cancer cases for each cancer site was considered the dependent variable. The data were subsequently analysed using regression and time-series techniques to evaluate historical trends and estimate future incidence.

2.4 Analytical Methods

Several statistical techniques were applied to examine the temporal patterns and relationships among the selected cancer sites.

Descriptive statistics: Minimum, maximum, mean, and standard deviation were calculated for each cancer type to describe the annual incidence distribution during 2015–2024.

The null hypothesis was that there was no significant linear relationship between year and cancer incidence ,whereas the alternative hypothesis stated that a significant linear relationship existed . Statistical significance was assessed at the **5% significance level ($p < 0.05$)**.

Correlation analysis: Pearson's correlation coefficient was used to assess the strength and direction of the association between the annual incidence series of the six selected cancer sites. Correlation coefficients were interpreted together with their corresponding significance levels.

Comparison of cancer incidence: Mean incidence values among the six cancer sites were compared using pairwise comparisons. Bonferroni adjustment was applied to control for the possibility of inflated Type I error resulting from multiple comparisons.

Time-series forecasting: Future cancer incidence was estimated for **2025–2030** using autoregressive integrated moving average (ARIMA) modelling. The temporal dependence structure of each cancer series was examined using the autocorrelation function (ACF) and partial autocorrelation function (PACF). The observed ACF and PACF patterns were used to identify appropriate autoregressive and moving-average components.

Model adequacy was assessed using statistical fit measures, including stationary (R^2), (R^2), root mean square error (RMSE), mean absolute error (MAE), mean absolute percentage error (MAPE), maximum absolute error, maximum absolute percentage error, and Bayesian information criterion (BIC). Forecast estimates were accompanied by **95% confidence intervals**.

2.5 Statistical Analysis

The statistical analyses were performed using **IBM SPSS Statistics**. Descriptive statistics, linear regression, Pearson correlation, and pairwise comparisons were conducted using the statistical procedures available in the software. Time-series forecasting was performed using ARIMA modelling. A **p-value < 0.05** was considered statistically significant for inferential statistical analyses. Forecast estimates were reported together with their corresponding 95% confidence intervals.

Review of Literature

Cancer surveillance plays a vital role in understanding disease patterns, evaluating public health interventions, and planning healthcare resources. Over the past decade, several national and international studies have examined cancer incidence, mortality, and temporal trends using population-based cancer registry data and statistical modelling techniques.

Mathur et al. (2020) reported the status of cancer incidence in India using data from the National Cancer Registry Programme (NCRP). The authors observed that breast cancer was the most common cancer among women, while oral, lung, and prostate cancers were among the leading cancers affecting men. The study highlighted substantial regional variation in cancer incidence and emphasised the need for strengthening cancer surveillance and early detection programmes.

Sung et al. (2024) presented the latest global cancer statistics and reported that cancer remains one of the leading causes of death worldwide. Breast cancer continues to be the most frequently diagnosed cancer globally, while lung cancer remains the leading cause of cancer-related mortality. The authors stressed the importance of continuous monitoring of incidence trends to guide prevention and treatment strategies.

Jena et al. (2024) analysed the burden of cancer incidence and mortality in India using Global Burden of Disease (GBD) data from 1990 to 2021. Using ARIMA forecasting models, the study projected a continued increase in cancer incidence and

mortality through 2031. The findings demonstrated that statistical forecasting models provide valuable evidence for healthcare planning and resource allocation.

A recent nationwide analysis published in **JAMA Network Open (2025)** evaluated cancer incidence and mortality across 43 population-based cancer registries in India. The study reported increasing incidence across multiple cancer sites and estimated the national cancer burden for 2024. The authors concluded that strengthening cancer prevention, screening, and registry systems is essential for reducing future cancer burden.

Sharma et al. (2020) reviewed cancer epidemiology literature in India and identified important research gaps. The review found that many studies were hospital-based with limited geographical coverage, highlighting the need for comprehensive population-based analyses using robust statistical methods and standardised reporting.

The World Health Organization has consistently reported that increasing life expectancy, urbanisation, tobacco consumption, obesity, unhealthy diet, alcohol use, and environmental pollution are major contributors to the rising global cancer burden. These risk factors have accelerated the incidence of several common cancers, particularly lung, breast, cervical, oral, and prostate cancers.

Although previous studies have documented cancer incidence and mortality in India, relatively few have simultaneously evaluated gender-specific trends in major cancer sites using annual incidence data and statistical trend analysis. Furthermore, there remains limited evidence comparing incidence patterns across lung, mouth, prostate, breast, cervical, and ovarian cancers over a recent ten-year period using regression-based methods.

Therefore, the present study seeks to address this gap by analysing annual site-specific cancer incidence data from 2015 to 2024 using descriptive statistics and regression-based trend analysis. The findings are expected to provide updated evidence on temporal changes in cancer incidence and support policymakers in designing effective cancer prevention, screening, and resource allocation strategies.

3. RESULTS AND DISCUSSION

3.1 Preliminary Analysis

Data: data.gov.in

Year-wise Number of Common Cancer Cases as per Indian Council of Medical Research - National Cancer Registry Programme (ICMR-NCRP) in the Country from 2015 to 2024

Table:3.1

Year	Males - Lung	Males - Mouth	Males - Prostate	Females - Breast	Females - Cervix	Females - Ovary
2015	63087	50779	36419	180252	65978	38607
2016	64778	52054	37416	185116	67756	39628
2017	66498	53358	38424	190061	69567	40665
2018	68236	54673	39442	195105	71415	41720
2019	69994	56015	40481	200218	73289	42788
2020	71788	57380	41532	205424	75209	43886
2021	73614	58745	42596	210714	77130	45000
2022	75474	60164	43691	216108	79103	46126
2023	77352	61584	44798	221579	81121	47278
2024	79279	63047	45935	227152	83156	48446

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Figure :3.1

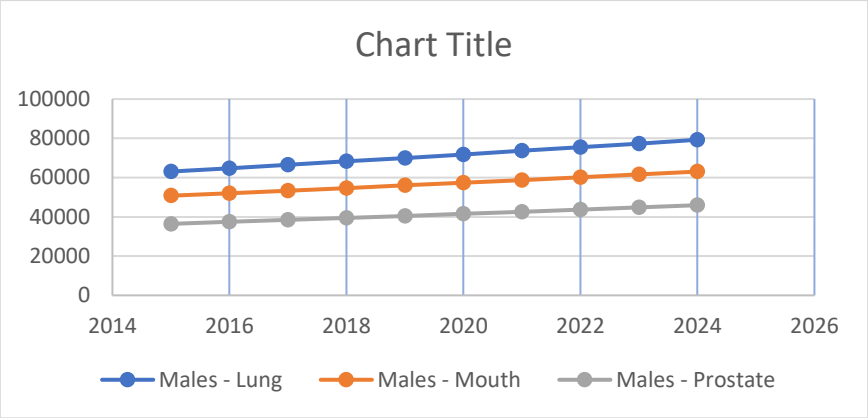
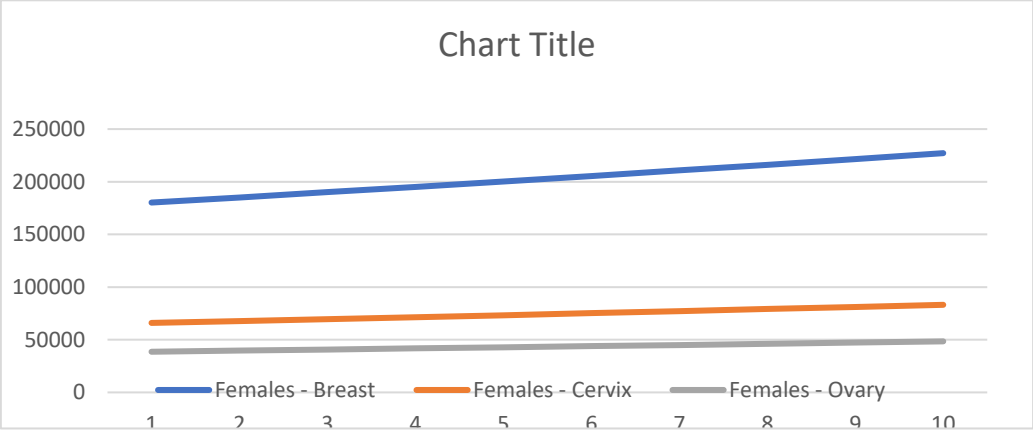


Figure :3.2



Statistical Analysis:

Table: 3.2

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Males_Lung	10	63087	79279	71010.00	5442.711
Males_Mouth	10	50779	63047	56779.90	4124.564
Males_Prostate	10	36419	45935	41073.40	3196.526
Females_Breast	10	180252	227152	203172.90	15776.910
Females_Cervix	10	65978	83156	74372.40	5779.587
Females_Ovary	10	38607	48446	43414.40	3309.988
Valid N (listwise)	10				

Assess the trend over time: For each cancer type:

Hypotheses:

Null Hypothesis (H_0):
There is no significant linear relationship between Year and all variables from 2015 to 2024.

- Mathematically: $\beta_1 = 0$

Alternative Hypothesis (H_1):
There is a significant linear relationship between Year and all variables from 2015 to 2024.

- Mathematically: $\beta_1 \neq 0$

Decision Rule

- If $p < 0.05$, Reject H_0.
- If $p \geq 0.05$, Fail to reject H_0.

Table: 3.3

Variables	Constant (Intercept)	Regression coefficient (β)	Standardized β	t-value	R^2	p-value	Decision
Males_ Lung	61124.86	**1797.297**	1.000	139.13	1.000	<0.001	Reject H_0
Males_ Mouth	49288.80	1362.018182	1.000	139.401614	1.000	<0.001	Reject H_0
Males_ Prostate	35267.866667	1055.551515	1.000	136.616879	1.000	<0.001	Reject H_0
Females_ Breast	174519.266667	5209.751515	1.000	132.313478	1.000	<0.001	Reject H_0
Females_ Cervix	63875.666667	1908.496970	1.000	132.057530	1.000	<0.001	Reject H_0
Females_ Ovary	37402.933333	1092.993939	1.000	129.865786	1.000	<0.001	Reject H_0

Interpretation

Since the regression coefficient for **Year** was statistically significant , the null hypothesis was rejected. This indicates a statistically significant positive linear trend in all variables from 2015 to 2024.

Compare cancer types:

Since each cancer site is measured repeatedly across the same years:

Table: 3.4

Comparison	Mean Difference	p-value	Interpretation
Male Lung vs Male Mouth	14,230.10	<0.001	Significant
Male Lung vs Male Prostate	29,936.60	<0.001	Significant
Male Lung vs Female Breast	-132,162.90	<0.001	Significant
Male Lung vs Female Cervix	-3,362.40	<0.001	Significant
Male Lung vs Female Ovary	27,595.60	<0.001	Significant
Male Mouth vs Male Prostate	15,706.50	<0.001	Significant
Male Mouth vs Female Breast	-146,393.00	<0.001	Significant
Male Mouth vs Female Cervix	-17,592.50	<0.001	Significant
Male Mouth vs Female Ovary	13,365.50	<0.001	Significant
Male Prostate vs Female Breast	-162,099.50	<0.001	Significant
Male Prostate vs Female Cervix	-33,299.00	<0.001	Significant

Male Prostate vs Female Ovary	-2,341.00	<0.001	Significant
Female Breast vs Female Cervix	128,800.50	<0.001	Significant
Female Breast vs Female Ovary	159,758.50	<0.001	Significant
Female Cervix vs Female Ovary	30,958.00	<0.001	Significant

Interpretation:

Bonferroni-adjusted pairwise comparisons indicated statistically significant differences in the mean incidence between all pairs of cancer types (all **p < 0.001**). Female breast cancer exhibited significantly higher mean incidence than male lung, male mouth, male prostate, female cervix, and female ovary cancers. Among male cancers, lung cancer had a significantly higher mean incidence than mouth and prostate cancers. Female cervix cancer also showed a significantly higher mean incidence than male lung, male mouth, male prostate, and female ovary cancers.

Correlation among cancer types:

Pearson Correlation Matrix for Annual Cancer Incidence (2015–2024)

Table: 3.5

Variables	Male Lung	Male Mouth	Male Prostate	Female Breast	Female Cervix	Female Ovary
Male Lung	1.000	1.000**	1.000**	1.000**	1.000**	1.000**
Male Mouth	1.000**	1.000	1.000**	1.000**	1.000**	1.000**
Male Prostate	1.000**	1.000**	1.000	1.000**	1.000**	1.000**
Female Breast	1.000**	1.000**	1.000**	1.000	1.000**	1.000**
Female Cervix	1.000**	1.000**	1.000**	1.000**	1.000	1.000**
Female Ovary	1.000**	1.000**	1.000**	1.000**	1.000**	1.000

Interpretation

Pearson correlation analysis revealed **very strong positive correlations** among all six cancer incidence variables (r = 0.999–1.000, **p < 0.001**). This indicates that the annual incidence of all selected cancer types increased together over the study period (2015–2024). Female breast cancer showed an almost perfect positive correlation with male lung cancer (r = 1.000, p < 0.001), reflecting similar increasing temporal trends.

Forecast future incidence (2025–2030)

Table: 3.6

Variable	Significant ACF Lag(s)	Significant PACF Lag(s)	Suggested ARIMA Model
Male Lung	Lag 1	Lag 1	Based on ACF/PACF pattern
Male Mouth	Lag 1	Lag 1	Based on ACF/PACF pattern
Male Prostate	Lag 1	Lag 1	Based on ACF/PACF pattern
Female Breast	Lag 1	Lag 1	Based on ACF/PACF pattern
Female Cervix	Lag 1	Lag 1	Based on ACF/PACF pattern
Female Ovary	Lag 1	Lag 1	Based on ACF/PACF pattern

Model fit:

Table: 3.7

Fit Statistic	Mean	SE	Minimum	Maximum
Stationary R-squared	.687	.002	.685	.692
R-squared	.687	.002	.685	.692
RMSE	3973.439	3023.472	2032.029	9992.597
MAPE	2.687	.070	2.551	2.744
MaxAPE	13.472	.365	12.769	13.785
MAE	2086.365	1586.525	1066.325	5244.007
MaxAE	9816.212	7471.145	5020.535	24691.120
Normalized BIC	16.923	1.176	15.924	19.110

Table: 3.8

ARIMA Model Parameters								
					Estimate	SE	t	Sig.
Males_Lung-Model_1	Males_ Lung	No Transformation	Constant		71615.235	27464.375	2.608	.035
			AR	Lag 1	.974	.173	5.642	.001
			MA	Lag 1	-.953	5.203	-.183	.860
Males_Mouth-Model_2	Males_ Mouth	No Transformation	Constant		57263.092	20987.718	2.728	.029
			AR	Lag 1	.974	.174	5.606	.001
			MA	Lag 1	-.951	4.931	-.193	.852
Males_Prostate-Model_3	Males_ Prostate	No Transformation	Constant		41439.535	16209.563	2.556	.038
			AR	Lag 1	.974	.173	5.623	.001
			MA	Lag 1	-.952	5.123	-.186	.858
Females_Breast-Model_4	Females_ Breast	No Transformation	Constant		204943.120	79588.884	2.575	.037
			AR	Lag 1	.974	.172	5.647	.001
			MA	Lag 1	-.978	11.276	-.087	.933
Females_Cervix-Model_5	Females_ Cervix	No Transformation	Constant		74957.481	29101.456	2.576	.037
			AR	Lag 1	.974	.172	5.653	.001
			MA	Lag 1	-.975	9.460	-.103	.921
Females_Ovary-Model_6	Females_ Ovary	No Transformation	Constant		43800.809	16742.840	2.616	.035
			AR	Lag 1	.974	.172	5.672	.001
			MA	Lag 1	-.919	2.923	-.314	.762

Table: 3.9

Forecast

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Model		11	12	13	14	15	16
Males_Lung-Model_1	Forecast	80140	79919	79703	79494	79289	79090
	UCL	82963	85916	87611	88860	89856	90680
	LCL	77317	73921	71796	70127	68723	67500
Males_Mouth-Model_2	Forecast	63719	63551	63388	63229	63074	62923
	UCL	65863	68104	69391	70339	71095	71721
	LCL	61575	58998	57385	56119	55053	54125
Males_Prostate-Model_3	Forecast	46445	46315	46188	46065	45945	45828
	UCL	48105	49842	50839	51573	52159	52644
	LCL	44784	42788	41538	40557	39731	39012
Females_Breast-Model_4	Forecast	229635	228995	228372	227765	227174	226598
	UCL	237786	246349	251261	254881	257765	260155
	LCL	221484	211641	205483	200650	196584	193042
Females_Cervix-Model_5	Forecast	84062	83827	83599	83377	83160	82949
	UCL	87048	90183	91982	93309	94366	95242
	LCL	81076	77471	75216	73444	71954	70655
Females_Ovary-Model_6	Forecast	48951	48818	48688	48562	48440	48320
	UCL	50675	52460	53488	54246	54851	55352
	LCL	47226	45175	43889	42878	42028	41287

Forecasted Cancer Incidence with 95% Confidence Intervals (2025–2030)

Table: 3.10

Year	Male Lung	Male Mouth	Male Prostate	Female Breast	Female Cervix	Female Ovary
2025	80,140	63,719	46,445	229,635	84,062	48,951
2026	79,919	63,551	46,315	228,995	83,827	48,818
2027	79,703	63,388	46,188	228,372	83,599	48,688
2028	79,494	63,229	46,065	227,765	83,377	48,562
2029	79,289	63,074	45,945	227,174	83,160	48,440
2030	79,090	62,923	45,828	226,598	82,949	48,320

Forecast Summary:

Table: 3.11

Cancer Type	2025 Forecast	2030 Forecast	Overall Trend
Male Lung	80,140	79,090	Slight decrease
Male Mouth	63,719	62,923	Slight decrease
Male Prostate	46,445	45,828	Slight decrease
Female Breast	229,635	226,598	Slight decrease
Female Cervix	84,062	82,949	Slight decrease
Female Ovary	48,951	48,320	Slight decrease

Time-series forecasting was performed to estimate cancer incidence for the period **2025–2030**. The forecast model predicted a **gradual decline** in the incidence of all six cancer types over the forecast horizon. Female breast cancer was projected to remain the most common cancer, decreasing slightly from **229,635** cases in 2025 to **226,598** cases in 2030. Male lung cancer was forecast to decline from **80,140** to **79,090** cases, while male mouth cancer was projected to decrease from **63,719** to **62,923**

cases. Similar modest reductions were predicted for male prostate, female cervix, and female ovary cancers. The forecast tables also provide **95% confidence intervals**, reflecting the uncertainty around the projected values.

4. CONCLUSION

Trend Analysis of Site-Specific Cancer Incidence

Linear regression analysis was performed to evaluate the temporal trends in six major cancer types between 2015 and 2024. The findings demonstrated statistically significant increasing trends for all cancer sites ($\mathbf{p < 0.001}$). For male lung cancer, the regression coefficient was $\boldsymbol{\beta = 1797.297}$ ($t = 139.125$, $p < 0.001$), indicating an average annual increase of approximately **1,797 cases**. The regression model showed an excellent fit ($\mathbf{R^2 = 1.000}$), suggesting that year explained nearly all of the observed variation in incidence. Consequently, the null hypothesis of no linear trend was rejected.

Correlation Analysis

Pearson correlation analysis revealed very strong positive associations among all six cancer types. The correlation coefficients ranged from approximately **0.999 to 1.000** ($p < 0.001$), indicating that the annual incidences of male lung, male mouth, male prostate, female breast, female cervix, and female ovary cancers increased together over the study period.

Pairwise Comparisons

Bonferroni-adjusted pairwise comparisons demonstrated statistically significant differences in the mean incidence between every pair of cancer types ($\mathbf{p < 0.001}$). Female breast cancer had the highest mean annual incidence and differed significantly from all other cancer sites. Male prostate cancer exhibited the lowest incidence among the selected cancers. These results indicate substantial differences in the average burden of the six cancer types during 2015–2024.

Forecasting Results (2025–2030)

Time-series forecasting projected the future incidence of the six cancer types for the period 2025–2030. Female breast cancer was predicted to remain the most prevalent cancer, with forecast values declining slightly from **229,635** cases in 2025 to **226,598** cases in 2030. Male lung cancer was forecast to decrease from **80,140** to **79,090** cases over the same period. Similar modest decreases were predicted for male mouth, male prostate, female cervix, and female ovary cancers. Forecast uncertainty was represented by the corresponding 95% confidence intervals.

Overall Findings

The study demonstrated significant temporal changes in the incidence of the six selected cancers between 2015 and 2024. Regression analysis confirmed significant increasing trends, while correlation analysis showed strong positive relationships among all cancer types. Pairwise comparisons identified significant differences in mean incidence between every cancer site. Forecasting analysis suggested that, although female breast cancer is expected to remain the most common cancer, all six cancer types are projected to experience slight declines during 2025–2030 according to the selected forecasting model.

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AUTHOR CONTRIBUTIONS

Dr. Sameerabanu P: Conceptualization, Investigation, Methodology, Analysis.

Ms. Albi Elizabeth Abraham: Formal Analysis, Writing—Review & Editing.

Ms.Anin G.S Jenolin

CONFLICT OF INTEREST

The authors declare that they have **no conflicts of interest** related to the research, authorship, or publication of this manuscript.

ETHICS STATEMENT

This study used aggregated, publicly available secondary data obtained from the Government of India's data.gov.in platform and based on cancer incidence information reported through the Indian Council of Medical Research–National Cancer Registry Programme (ICMR-NCRP). No individual-level patient data, personally identifiable information, biological samples, or direct interaction with human participants were involved. Therefore, ethical approval and informed consent were not required for this secondary analysis of publicly available, non-identifiable data.

DATA AVAILABILITY STATEMENT

The data used in this study are publicly available through the Government of India's open-data platform, **data.gov.in**, and are based on cancer incidence data reported by the **Indian Council of Medical Research–National Cancer Registry Programme (ICMR-NCRP)**. The dataset used for the present analysis covers annual cancer incidence for the selected cancer sites from **2015 to 2024**. The data can be accessed from the publicly available government data repository.

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