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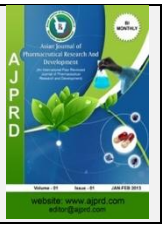

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Review Article

Epidemiological Study of Various Malignancies in Rajasthan: A Comprehensive Analysis

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A B S T R A C T

Objective: Cancer epidemiology systematically studies risk factors, incidence, and prevention strategies using data-driven methods. Accurate cancer surveillance and registration are vital for effective control. Still, in developing countries, challenges like limited healthcare access, poor data infrastructure, and lack of trained personnel hinder proper reporting and analysis. **Data Source:** The investigators searched multiple databases (e.g., PubMed, Google Scholar, Web of Science) focused on cancer in Rajasthan, India, or globally. Out of 150 sources screened, 99 articles, books, and government reports met the inclusion criteria and were selected for final analysis.

Summary: According to the available literature, Cancer epidemiology in Rajasthan highlights oral cavity, breast, cervix, lung, brain and prostate cancers as the most common types, with oral and lung cancers predominant among males due to high tobacco use. Breast and cervical cancers are leading concerns for women, often linked to late diagnosis and poor awareness, especially in rural areas.

Conclusion: Rajasthan requires urgent attention to strengthening cancer surveillance, promoting public awareness, and encouraging region-specific research, as these are essential to improving health outcomes and ensuring equitable healthcare planning and policy-making.

Keywords: Cancer, Rajasthan, Epidemiology, Etiology, Cancer screening.

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INTRODUCTION

Abnormal proliferation of cells in the body can lead to the development of tumors. Tumors that can invade the surrounding normal tissue and spread (metastasise) throughout the body through the circulatory or lymphatic system are considered malignant tumors, more accurately called cancer.[1-4] There are more than a hundred types of cancer because malignant growth can appear anywhere in the body.[5]Different patterns of cancer in multiple geographic areas can depend on genetic, environmental, dietary, occupational, and other factors.[5-6] It is important to understand the different patterns of cancer in a subset of the population. Known cancer risk factors include social determinants, lifestyle factors, occupational stress, infectious pathogens, and genetic and posterior changes.[7-9]

Cancer epidemiology is a scientific, systematic, and data-driven study of causes, risk factors, analysis of the distribution of cancer incidence, and events that increase or decrease the incidence of cancer in a particular population.[10-13] Epidemiological methods are essential for discovering cancer risk and prognostic factors and assessing cancer preventive interventions.[12,14]The goal of cancer epidemiology is to understand what risk factors are associated with the disease and how a group of individuals can prevent the disease. Due to the observatory nature of epidemiology, it is not possible to provide an answer to a particular person as to what caused the disease.[15-16]Epidemiologic cancer research encompasses three main types. Descriptive epidemiology examines patterns and trends in disease occurrence within specific populations. Analytic epidemiology investigates the causes and risk factors that contribute to the development of cancer. Clinical

epidemiology focuses on evaluating screening methods and assessing the effectiveness of prevention strategies on health outcomes.[17-21]

Epidemiological measurements of morbidity include incidence and prevalence. Incidence measures the occurrence of new cases of disease, taking into account the amount of time a person has been disease-free.[22] An incidence rate is defined as the number of new cases of a disease in the population divided by the sum of the periods of observation (or time at risk) for all individuals within the population.[23]Cancer monitoring, an important element of epidemiology and public health practices, provides information on the burden of different types of cancer in highly identified populations and anticancer interventions through evidence-based public health programs.[24-25] Evaluating the success of the intervention, diagnostic, therapeutic, and palliative care information needs to be extensively evaluated using clinical epidemiological studies, systematic review methods, and meta-analysis models to support evidence-based protocols and design approaches to meet clinical priorities. Cancer surveillance relies on statistics, especially data from both mortality and risk factor prevalence studies.[26-30]

Cancer registration is an important tool for planning and monitoring all levels of prevention efforts.[31]Population-based cancer registries (PBCR) and Hospital-based cancer registries (HBCR) are an essential part of any national programme of cancer control that aims to provide crucial data on cancer incidence, survival, and mortality, and thus provide a useful pathway to cancer research and an instrument to support cancer control.[32-35]Research on the effectiveness of cancer screening remains a challenge. Screening can be detrimental, and few cancers will benefit from screening. Accurate reporting of cancer profiles from a region has many restrictions, especially in developing countries.[36-37] The problem of proper recording in these situations represents a serious handicap for medical statistics and research. Challenges in collecting and analysing cancer registration data in developing countries include a lack of basic health care, lack of stable population, lack of trained staff, inadequate follow-up care, and census estimates.[38-40]

Epidemiologic Status of Cancer in the World

In 1950, the World Health Organization sponsored an international colloquium that led to the establishment of the International Agency for Research on Cancer (IARC) in 1965. The IARC was created to carry out multidisciplinary research into the causes of cancer in humans.[41-43]Initially, its evaluations relied solely on epidemiological data, but over time, the criteria expanded to include experimental evidence as well.[42-43] Today, cancer is a growing global health burden and one of the leading causes of death worldwide. It ranks second only to cardiovascular diseases in terms of mortality.[44-48]Among all non-communicable diseases—including heart disease, chronic respiratory conditions, and diabetes—cancer remains a critical public health concern.[49] According to GLOBOCAN data, the global landscape of cancer incidence and mortality shifted between 2020 and 2022. In 2020, the top five cancers by incidence were breast (11.7%), lung (11.4%), colorectal (10.0%), prostate (7.3%), and stomach (5.6%) cancers. By 2022, lung cancer (13.1%) had overtaken breast cancer (12.2%) as the most commonly diagnosed cancer, followed by colorectal (9.8%), prostate (7.8%), and stomach (4.9%) cancers. In terms of mortality, lung cancer remained the leading cause of cancer death in both years-accounting for 18.0% of all cancer deaths in 2020 and rising to 18.7% in 2022. Colorectal cancer was the second leading cause of death (9.4% in 2020, 9.3% in 2022), followed by liver (8.3% in 2020, 7.8% in 2022), stomach (7.7% in 2020, 6.8% in 2022), and breast cancer (6.9% in both years). These trends highlight a growing global burden of lung and colorectal cancers in both incidence and mortality, while stomach and liver cancers show a gradual decline. The shifts reflect changes in risk factors, screening, and treatment advances, emphasising the need for continued global cancer surveillance and targeted prevention strategies.[50-53] According to a WHO report on cancer 2020, in 2018, there were an estimated 18.1 million new cases and 9.6 million deaths from cancer and accounting for nearly 10 million deaths in 2020, or nearly one in six deaths is due to cancer in the world. Globally, over 35 million of the world population will be infected with cancer by 2050.[54-56]

Epidemiologic Status of Cancer in India

Cancer registration in India began in a more structured way when the Indian Cancer Society (ICS) established the country's first population-based cancer registry in Bombay (now Mumbai) in 1963.[57] The ICS, a non-profit organization founded in 1951 by Dr. Darab Jehangir Jussawalla and Mr. Naval Tata, has been dedicated to promoting cancer awareness, early detection, treatment, and survival. It also plays a key role in collecting data on cancer incidence and mortality from various cities across India.[58] Prior to 1964, cancer-related data in India were largely derived from limited surveys. The establishment of PBCRs in Bombay (1964), Pune (1973), Aurangabad (1978), and later in Ahmedabad and Nagpur (1980) marked the beginning of continuous and systematic data collection on cancer incidence. A major milestone in cancer registration came in 1982 with the launch of the National Cancer Registry Programme by the ICMR. Based in New Delhi, the ICMR is the country's premier body for biomedical research, focusing on the control of communicable diseases, cancer, cardiovascular conditions, diabetes, and blindness, and for formulating public health strategies.[59–60] The NCRP was initiated in 1981 to collect reliable cancer data, conduct epidemiological studies, support cancer control programs, and raise awareness, as highlighted in the Annual Report 2020–2021 by the National Centre for Disease Informatics and Research, ICMR. The NCRP began with three population-based cancer registries—one existing in Bombay and new ones in Bangalore and Madras—and three hospital-based registries located in Chandigarh, Dibrugarh, and Trivandrum. The program later expanded to include urban PBCRs in Bhopal and Delhi (1987), a rural PBCR in Barshi, Maharashtra (1987), and hospital-based registries at the leading hospitals of the PBCR sites in Bangalore, Bombay, and Madras (1986). Additionally, a hospital-based cancer registry operated in Chandigarh from 1982 to 1992. Currently, the NCRP's coordinating unit provides oversight, guidelines, and quality control for a network that includes six population-based and five hospital-based cancer registries.[61]

India is also experiencing a rapid increase in cancer cases. The population" with "PBCRs and HBCRs have gradually grown, and now there are 38 PBCRs and 189 HBCRs in

the NCRP network.[62]According to GLOBOCAN data, India saw an estimated 1.39 million new cancer cases in 2020, rising to about 1.46 million in 2022, with a crude incidence rate of 100.4 per 100,000 population. The top five cancers by incidence in 2022 were breast (15.2%), oral cavity (10.3%), cervix uteri (9.4%), lung (5.5%), and colorectum (5.2%). For cancer mortality, the leading sites were oral cavity (12.2%), lung (9.6%), stomach (6.4%), breast (6.2%), and colorectum (5.8%). Compared to 2020, breast cancer remained the most common, but oral and cervical cancers continued to represent a significant burden, reflecting India's unique risk profile-particularly high rates of tobacco use and Human papillomavirus (HPV) infection. In 2022, cancer deaths in India were estimated at 916,827, with a slightly higher burden in men (470,055) than women (446,772). The age-adjusted incidence and mortality rates in India remain lower than global averages, partly due to underreporting, but the cancer burden is projected to rise by nearly 13% by 2025. These data underscore the persistent challenge of oral, breast, and cervical cancers in India, distinct from global patterns where lung and colorectal cancers dominate.[63-65]

In India, the 2 most carcinogenic substances used publicly are Alcohol & Tobacco. According to the NFHS-5(2019-2021) report, there are over 1 million females and approximately 1 million males who use alcohol and tobacco. Arunachal Pradesh had the highest alcohol consumption rate in India.[66-67] Tobacco is the most important identified cause of cancer and was responsible for 30 to 50% of cancers in men and about 10-15% of cancers in women. In India, 42.4% of men, 14.2% of women and 28.6%(266.8 million) of all adults currently use tobacco (smoked and/or smokeless tobacco).[68-70]

Table 1: Leading cancer sites in Females [73,74,76,77]

1984-1988	%	1990	%	1990-2004	%	2004-2008	%
Cervix (180)	18.18	Breast (174)	19.42	Breast (174)	20.44	Breast (174)	25.6
Breast (174)	17.93	Cervix (180)	18.2	Cervix (180)	14.99	Cervix (180)	10.26
Ovary (183)	6.6	Ovary (183)	4.03	Ovary (183)	4.35	Ovary (183)	5.4
Skin (173)	4.2	Rectum (154)	3.56	Brain (191)	3.8	Brain (191)	3.68
Myeloid (205)	4.03	Esophagus (150)	3.56	Esophagus (150)	3.67	Esophagus (150)	3.4

Table 2: leading cancer sites in Males [73,74,76,77]

1984-1988	%	1990	%	1990-2004	%	2004-2008	%
Oropharynx (146)	7.55	Prostate (185)	11.37	Lungs (162)	8.45	Lungs (162)	13.25
Hypopharynx (148)	6.35	Urinary Bladder (188)	9.08	Prostate (185)	7.12	Larynx (161)	5.35
Skin (173)	6.35	Lungs (162)	5.75	Brain (191)	6.04	Oropharynx (146)	5.09
Lip-Pharynx (149)	5.75	Lymph Nodes (196)	5.57	Urinary Bladder (188)	5.31	Brain (191)	4.84
Urinary Bladder (188)	5.01	Tongue (141)	4.99	Esophagus (150)	4.67	Tongue (141)	4.62

Epidemiologic Study of Cancer in Rajasthan

Rajasthan's total population, as per the 2011 census, is above 68 million.[71]Rajasthan's public healthcare infrastructure comprises 3,139 facilities, including 2,463 Primary Health Centers, 579 Community Health Centers, 64 Sub-Divisional Hospitals, and 33 District Hospitals.[72]Regarding the case of Rajasthan, the epidemiological study of cancer is limited and has already been done; accordingly, various malignancy patterns have been out in the human body, site-wise distribution of cancer, and comparison with different states in India. A few studies have been published previously by Sharma *et al.* in 1992, 1994, 2009, 2014, Deotra *et al.* in 2017, Gurjar & Patel in 2017, Bansal *et al.* in 2018, Rajpurohit *et al.* in 2020, Singh *et al.* in 2020, Choudhary *et al.* in 2020, and Swain *et al.* in 2022.[73-83] Previous studies revealed that between 1984 and 1988, a total of 2662 new cancer cases were reported in the Jodhpur region, with males accounting for 56.2% (1,496 cases) and females 43.8% (1,166 cases).[73] In the Jaipur region, 2509 new cases comprising 57.5% males (1,443 cases) and 42.5% females (1,066 cases) in 1990[74], 21868 new cases—59.1% male (12,926 cases) and 40.9% female (8,942 cases) from 1990 to 2004[76] and continued between 2004 and 2008, 34486 new cases were reported with 58.6% males (20,202 cases) and 41.4% females (14,284 cases)[77] through analysis of approximately 4 lakhs histopathology and cytological reports. Table 1& 2 provides information on the leading tumors sites of males and females from 1984 to 2008.[73,74,76,77]An estimated 1 million new cases of cancer and nearly 0.7 million deaths from cancer were projected by 2026.[84,85]

Table 3: Percentage distribution of use of tobacco and alcohol consumption in Rajasthan [69,93-96]

Survey & Year	Men Tobacco Use (%)	Women Tobacco Use (%)	Men Alcohol Use (%)	Women Alcohol Use (%)
NFHS-4 (2015-16)	46.9	6.3	15.9	0.1
NFHS-5 (2019-21)	42	6.9	11	0.3
GATS-1 (2009-10)	47.9	20.3	NA	NA
GATS-2 (2016-17)	39.6	9	NA	NA

Cancer epidemiology in Rajasthan reveals distinct regional variations influenced by environmental, demographic, and socio-cultural factors. Based on a range of epidemiological studies conducted across Rajasthan, the top five most commonly reported cancer sites in the state are the oral cavity, breast, cervix, lung, and head and neck (excluding

oral cavity). Oral cavity cancers, including cancers of the mouth and tongue, are consistently the most prevalent among males, particularly in western and central Rajasthan, largely attributed to the widespread use of tobacco and betel nut.[73,76,77] Breast cancer ranks as the leading cancer among females, affecting women primarily in the 30–60 age group. Several studies highlight delayed diagnosis and lack of awareness as key challenges in managing breast cancer.[76,79,81] Cervical cancer is also a major health burden for women in Rajasthan, especially in rural areas, with contributing factors such as poor genital hygiene, early marriage, and absence of HPV vaccination.[74,78] Lung cancer, though less common than the aforementioned types, is increasingly reported in both sexes, with tobacco smoking and environmental exposure cited as major causes.[82] Head and neck cancers, excluding oral cavity, form the fifth most frequent group, often associated with similar risk factors as oral cancers—namely, tobacco use and alcohol consumption. Studies also emphasise the therapeutic challenges in treating these cancers, especially in resource-limited settings in southern Rajasthan.[80] Testicular and cutaneous malignancies, though less common, exhibit unique clinicopathological profiles.[75,83] Overall, these findings underscore the pressing need for targeted cancer prevention, early screening, and region-specific public health strategies in Rajasthan.

Etiological Causes of Cancer

Over the past three decades, researchers have made significant efforts to identify cancer-causing substances found in homes, workplaces, and the environment. The evidence linking these substances to cancer comes from three main sources: studies involving humans, research on animals, and laboratory tests using human cells. Each of these types of evidence plays a crucial role in guiding public health decisions on whether exposure to specific carcinogens should be limited or eliminated.[86,87]There are most significant factors highlighted in this study that were a high frequency of alcohol related cancers (upper aerodigestive tract, breast, colon, rectum, liver,) and tobacco related cancers (Lung, cervix, ovary, kidney, urinary bladder, myeloid leukaemia, upper aerodigestive tract, stomach, colon, rectum, liver, pancreas,) in male and female population. Etiological causes of cancer are fundamentally three sorts of carcinogenesis: Chemical carcinogenesis (benzpyrene, amphibole and over 800 chemicals), physical carcinogenesis (radiation, actinic ray), biological carcinogenesis (viruses, bacteria, fungi, etc.).[88]

Various carcinogens are linked to specific cancers, with differing levels of evidence. Lung cancer is strongly associated with exposures such as asbestos, arsenic, diesel exhaust, radon, tobacco smoke, and industrial processes like welding and aluminium production. Limited evidence points to risks from acid mists, benzene, biomass smoke, bitumen exposure, and certain chemicals. Breast cancer is linked to alcohol, hormone therapies, and radiation, while limited evidence connects it to ethylene oxide, night shift work, and tobacco. Prostate cancer lacks agents with strong evidence, but limited links exist with cadmium, red meat. Cervical cancer is strongly associated with HPV types 16 and 18, tobacco use, and hormone use; less common HPV types have limited evidence. Ovarian cancer is linked to asbestos, hormone therapy, tobacco, and radiation, with some concern over talc use. Esophageal cancer is caused by alcohol, tobacco, betel quid, and radiation, while limited evidence implicates hot beverages, pickled vegetables, and rubber industry exposure. Oropharyngeal cancer is linked to HPV-16, and laryngeal cancer shares causes with esophageal cancer, including asbestos, alcohol, and tobacco, with limited evidence for bitumens and secondhand smoke.[89-91]

A classic example of using epidemiology as a tool to investigate preventable factors associated with cancer is the investigation of tobacco carcinogenicity.[92]Tobacco and alcohol have been integral parts of daily life since ancient times, yet both are now recognised as significant carcinogens. The widespread and long-term use of these substances, often without awareness of their harmful effects, has contributed substantially to the development of various malignancies. Numerous recent studies have confirmed that both tobacco and alcohol are carcinogenic to humans, with sufficient supporting evidence. Notably, alcohol consumption in Rajasthan declined by 8% between 2004 and 2012.[93] The data in Table 3 also reflect a downward trend in tobacco and alcohol use during this period. In 2010, the average monthly expenditure on smoking tobacco in Rajasthan was ₹488.70, which rose to ₹1,258.50 by 2017.[69,94-96] Additionally, radon exposure is a known lung carcinogen, which was found to exceed the recommended annual effective dose limit of 0.1 mSv/year set by the World Health Organization and the European Union Council.[97]

CONCLUSION AND RECOMMENDATIONS

This study highlights the significant burden of tobacco- and alcohol-related cancers, particularly lung, breast, and cervical cancers, within the community. Alarmingly, approximately 50% of all cancers in males are linked to tobacco and alcohol use, a large portion of which could be prevented through robust anti-tobacco and anti-alcohol interventions. Public education campaigns focusing on the risks of tobacco, alcohol, and other carcinogens, along with the promotion of healthy dietary practices and lifestyle changes, are critical components of cancer prevention at the primary level. However, other potential etiological factors—such as environmental exposures, dietary habits, and lifestyle patterns—also warrant immediate investigation. Despite being one of India's largest and most populous states, Rajasthan remains significantly underrepresented in epidemiological cancer research. National health surveys often prioritise urban and more developed regions, overlooking the unique socio-demographic, environmental, and cultural factors that shape disease patterns in Rajasthan, especially in rural and tribal communities. This lack of representation hampers the development of targeted public health strategies that reflect the state's specific needs. Cancer awareness regarding its causes, prevention, and treatment must reach every individual. Reliable surveillance of cancer incidence and mortality provides a foundation for setting policy priorities and evaluating the effectiveness of public health interventions. These surveillance efforts must be continuously updated to adapt to evolving local conditions. Thus, feasibility studies are essential to assess and improve the implementation of these programs.

The absence of a systematic data collection and record-keeping infrastructure further complicates efforts to

understand and address the cancer burden in Rajasthan. Notably, no substantial epidemiological cancer research has been published in the state since 2018. Strengthening cancer registries and data systems is therefore crucial to enable early detection, monitor trends, and implement effective prevention strategies. Government involvement is vital in initiating comprehensive cancer surveillance systems that can inform policy-making and future preparedness.This review draws from key epidemiological research conducted over the past 30 years, which has helped illuminate the scope of the cancer burden in Rajasthan. It identifies critical gaps and underscores the importance of ongoing research to confront emerging public health challenges. The primary aim of this review is to emphasise the need for consistent and well-supported epidemiological studies in Rajasthan.[98,99] Encouragement and collaboration from researchers, public health professionals, NGOs, government agencies, and academic institutions are essential. Neglecting cancer epidemiology in Rajasthan carries serious consequences. Without localised data, public health initiatives may fail to reflect the actual disease burden, leading to misdirected resources and ineffective interventions. Additionally, region-specific threats, such as vector-borne diseases influenced by the state's arid climate, may remain undetected. The absence of accurate health data weakens emergency preparedness and exacerbates health inequities, ultimately undermining the resilience of Rajasthan's healthcare system.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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