



Exploring the Burden of Cancer in Pakistan: An Analysis of 2019 Data

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Abstract

Cancer has become a growing burden in Pakistan in recent times, posing a significant cause for concern. The World Health Organization has reported a steady increase in the incidence of cancer in Pakistan. According to the present study, breast cancer (24.1%), oral cavity (9.6%), colorectum (4.9%), esophagus (4.2%), and liver cancer (3.9%) were the five most prevalent cancers. Males were more likely to have oral cavity cancer (14.9%), colorectum cancer (6.8%), liver cancer (6.4%), prostate cancer (6.0%), and lung cancer (6.0%). In women (41.6%), breast (6.9%), oral cavity (5.5%), cervix (4.7%), and uterus cancer (4.1%) were the most common cancers. Middle-aged people (43.0%) were most likely to develop cancer, followed by seniors (30.0%) and adults (20.0%). Children and adolescents were most likely to develop cancers of the central nervous system (CNS), leukemia (18.7%), and Hodgkin (17.3%), followed by breast, oral cavity, colorectum, and prostate at other ages. Most patients were from Punjab (40.4%) and Sindh (32.2%). Approximately 30.0% of patients were diagnosed at stage III and stage IV. In terms of registered cases, breast cancer, oral cavity cancer, colon cancer, esophagus cancer, and liver cancer are among the highest. In the future, this information may prove useful for assessing the effectiveness of interventions.

Keywords Cancer · Registry · Statistics epidemiology · PAECR · Pakistan

Abbreviations

WHO	World Health Organization
HPV	Human Papillomavirus
HBV	Hepatitis B virus
HIV	Human Immunodeficiency Virus
AECHs	Atomic Energy Cancer Hospitals
NM&O	Nuclear Medicine & Oncology
PAEC	Pakistan Atomic Energy Commission
PAECR	PAEC Annual Cancer Registry Report
DMIS	Directorate of Management Information Systems
KPK	Khyber Pakhtunkhwa
AJCC	American Joint Committee on Cancer
AJK	Azad Jammu and Kashmir

1 Introduction

Globally, 18.1 million new cancer cases are diagnosed yearly, and 9.6 million deaths occur before age 70 [1, 2]. The study reveals that cancer holds the grim distinction of being the leading cause of death in a significant number of countries, specifically in 91 out of 172 nations [3, 4]. In 2040, there will be 29.5 million cancer cases and 16.3 million deaths [5, 6]. The global landscape of cancer is increasingly burdened by emerging challenges attributed to factors such as rapid urbanization [7, 8], aging populations [9, 10], inactivity [11, 12], unhealthy lifestyles [13, 14], and air pollution [15, 16]. Based on the World Health Organization (WHO) fact sheet released in February 2017, cancer ranked among the top causes of mortality globally in 2015, accounting for 1 in 6 deaths worldwide. This highlights the substantial impact of cancer as a leading contributor to the global burden of disease and underscores the urgent need for effective strategies and interventions to prevent, diagnose, and manage this pervasive health challenge [7, 8], aging populations [9, 10], sedentary lifestyles [11, 12], unhealthy behaviors [13, 14], and environmental factors such as air pollution [15, 16]. [17, 18]. Estimates indicate that in 2019, there were a reported 140,690 cases of cancer [19, 20]. Most of these patients were battling cancer for the rest of

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their lives [21]. A study conducted in 2012 revealed that approximately 63,415 males and 85,590 females in Pakistan were diagnosed with cancer. These staggering numbers highlight the significant burden of cancer on both genders in the country and emphasize the need for comprehensive efforts to prevent, diagnose, and manage cancer cases in Pakistan [20, 22]. Lung cancer remains the leading cause of cancer-related deaths worldwide [23, 24], while breast cancer remains the leading cause of cancer-related deaths in Pakistan [25]. Several factors contribute to cancer risk, including hormonal [26], hereditary [27], metabolic [28], and autoimmune factors [29, 30]. In addition, cancer can be caused by external factors such as smoking, alcohol consumption, dietary imbalance, radiation exposure, or infections such as Human Papillomavirus (HPV), Hepatitis B virus (HBV), Human Immunodeficiency Virus (HIV), and *H. Pylori* in Pakistan [31, 32].

Data from cancer registries is an effective tool for setting goals, monitoring progress, and evaluating cancer programs' outcomes. A Cancer Registry is a system for collecting patient data that is then compiled into a summary of the patient's history, diagnosis, treatment, and status. Pakistan has 17 cancer institutes, known as Atomic Energy Cancer Hospitals (AECHs), which serve as the primary registrars for the majority of cancer patients in the country. These hospitals are operated in collaboration with the NM&O (Nuclear Medicine & Oncology) Division of Pakistan Atomic Energy Commission (PAEC), which is the largest cancer service provider in Pakistan. The PAEC Annual Cancer Registry Report (PAECR) is a joint effort between NM&O Division of PAEC and these hospitals to gather comprehensive data on cancer cases in the country. Pakistan has 190 million people, making it one of the most populated countries in South Asia. Pakistan is a country with a very diverse and heterogeneous population. There are six major ethnic groups making up the majority of the Pakistani population. As a result of its heterogeneity, regions populated by different ethnic groups have different cancer statistics. Given the absence of available studies on cancer statistics in Pakistan, our aim is to conduct a comprehensive study to provide much-needed information in this regard. This study will contribute to filling the knowledge gap and help shed light on the current status of cancer prevalence, types, and other relevant data specific to Pakistan.

1.1 Methods

This study presents the data for 2019. 40,797 cancer patients were registered that year. Detailed patient descriptions and demographic, staging, and site information are included. The NM&O Division collected cancer registry data from 17 cancer institutes every quarter in Pakistan. A cancer registry analysis tool developed by the Directorate of Management

Information Systems (DMIS), PAECR, is used to analyze the data based on ICD-10 codes. As part of its role, this directorate provides key support for the cancer registry project, including software, hardware, and training.

Patients were categorized by gender, age, and region. Children (0–9 years), Adolescents (10–19 years), Adults (20–39 years), Middle-aged (40–59 years), and Seniors (> 60 years) were the age groups. It presents data on cancer patients in various divisions and districts. In Khyber Pakhtunkhwa (KPK), the Federally

In order to evaluate a patient's disease at diagnosis, estimate their prognosis, guide treatment, evaluate therapy, and access early cancer detection results, staging helps physicians evaluate their patient's disease. Our study used the tumor (T), nodes (N), and metastases (M) (TNM) Staging Classification based on the American Joint Committee on Cancer (AJCC) system. The "unknown" category in this document represents patients with unknown or unspecified stages i.e., patients who have not arrived or forgone further treatment. In this report, stage 0, representing carcinoma-in-situ, is not included. The AJCC does not have a staging system for cancers such as leukemia, unknown primary, and primary brain tumors.

2 Results

2.1 Gender-Wise Distribution of Top 10 Cancers

A total of 40,797 cancer cases were reported, with 23,021 (56%) being female and 17,776 (44%) being male (Fig. 1A). The most common cancer among all patients are breast cancer, accounting for 24.1% of cases, followed by oral cavity cancer (9.6%), colorectal cancer (4.9%), esophageal cancer (4.2%), liver cancer (3.9%), ovarian cancer (3.8%), central nervous system cancer (3.8%), non-Hodgkin lymphoma (3.6%), lung cancer (3.5%), and prostate cancer (2.7%) (Fig. 1B). Among male patients, the most prevalent cancers were oral cavity (14.9%), colorectal (6.8%), liver (6.8%), prostate (6.2%), lung (6.5%), non-Hodgkin lymphoma (5.6%), esophageal (4.8%), bladder (4.8%), and laryngology (3.5%) (Fig. 1C). In females, the top 10 most prevalent cancers were breast (41.6%), ovary (6.8%), oral cavity (5.5%), cervix (4%), uterus (4.1%), esophagus (3.8%), colorectum (3.5%), non-Hodgkin lymphoma (2.4%), central nervous system (2.3%), and thyroid (2.2%) (Fig. 1D)."

2.2 Age-Wise Distribution of Top 10 Cancers

In this study, the patient population was stratified by age group, with 2% being children, 4% being adolescents, 20% being adults, 43% being middle-aged, and 31% being senior citizens (Fig. 2A). The most common cancers among

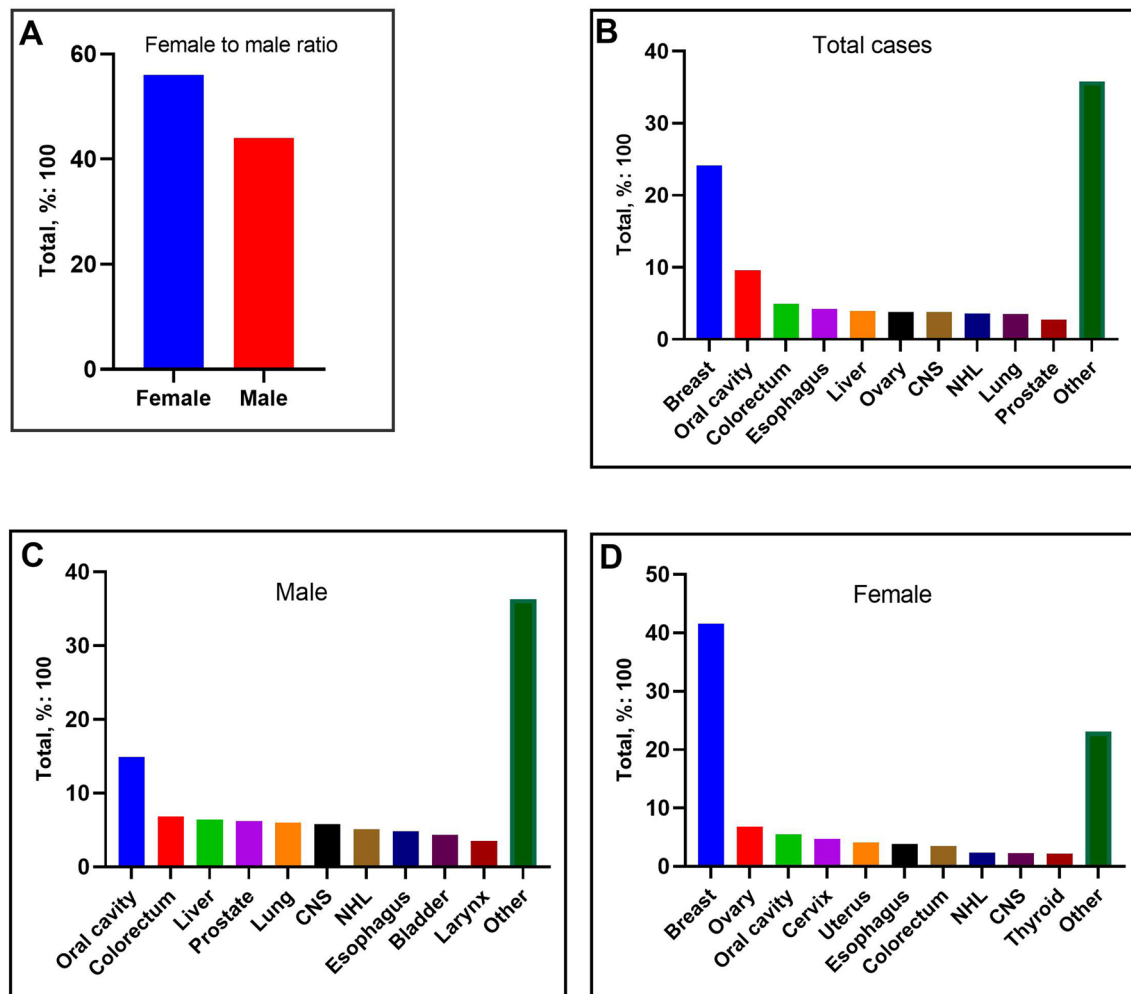


Fig. 1 **A** Male to female. **B** Top 10 cancers among Pakistani population register at PAERC. **C, D** Top 10 cancers among males and females

children were central nervous system (19.6%), leukemia (18.7%), Hodgkin's disease (17.3%), kidney cancer (10.3%), orbit (9.8%), sarcoma (7.2%), bone (5%), non-Hodgkin lymphoma (4%), melanoma of the uvea (1%), and ovary (1%) (Fig. 2B). Adolescents were most commonly diagnosed with bone cancer (14.1%), followed by leukemia (11.9%), Hodgkin's disease (11.8%), sarcoma (7.4%), non-Hodgkin lymphoma (6.5%), colorectal cancer (5.2%), ovarian cancer (5.4%), nasopharyngeal cancer (3.9%), and thyroid cancer (1.8%) (Fig. 2C). Adults had a higher prevalence of breast cancer (25.1%), followed by an oral cavity (9.9%), colorectal (7.4%), central nervous system (6.2%), ovarian (4.5%), esophageal (3.9%), thyroid (3.3%), non-Hodgkin lymphoma (3.2%), leukemia (3.0%), and sarcoma (2.8%) (Fig. 2D). Middle-aged patients were found to have a higher prevalence of breast cancer (31.2%), followed by an oral cavity (10.9%), colorectal (4.9%), ovarian (4.4%), liver (4.3%), esophageal (4.3%), cervical (3.5%), non-Hodgkin lymphoma (3.0%), lung (3.0%), and brain (2.8%) (Fig. 2E). Among

senior citizens, the most prevalent cancer was breast cancer (17.0%), followed by the oral cavity (9.2%), prostate (7.3%), lung (6.2%), liver (5.8%), esophagus (5%), bladder (4.5%), non-Hodgkin lymphoma (4.2%), colorectal (4.4%), and skin (3.4%) (Fig. 2F)."

2.3 Region-Wise Distribution of Cancer

A total of 233 cases were reported among males and 382 cases among females. The most prevalent cancer among males in Islamabad was prostate cancer (9.9%), followed by liver cancer (7.7%), oral cavity cancer (7.7%), colorectal cancer (7.3%), and lung cancer (5.3%). The prevalence of other types of cancer was less than 5.0% (Fig. 3A). Among females in Islamabad, breast cancer was the most prevalent (46.3%), followed by uterine cancer (9.4%), ovarian cancer (7.1%), colorectal cancer (5.5%), and less than 5.0%, with other types of cancer (Fig. 3B).

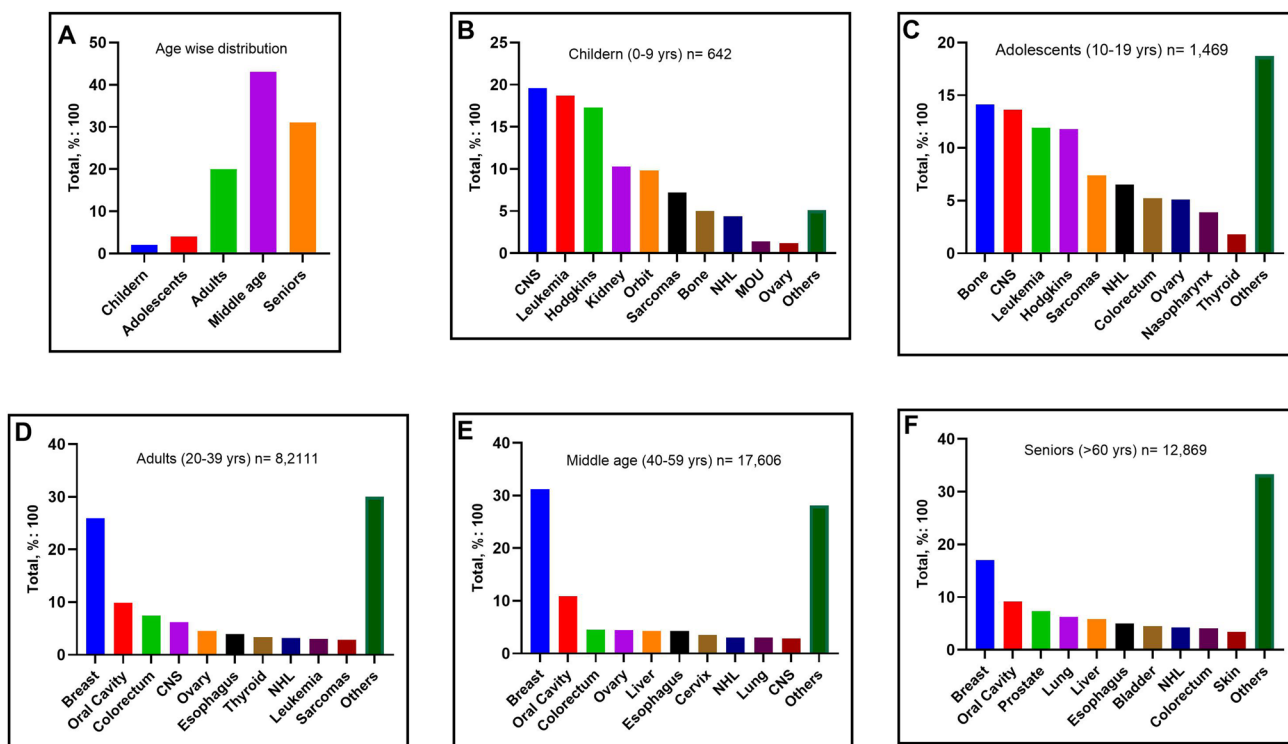


Fig. 2 A Age-wise distribution of cancers. B Top 10 cancers among children. C Top 10 cancers among adolescents. D Top 10 cancers among adults. E Top 10 cancers among middle aged people. F Top 10 cancers among senior citizens

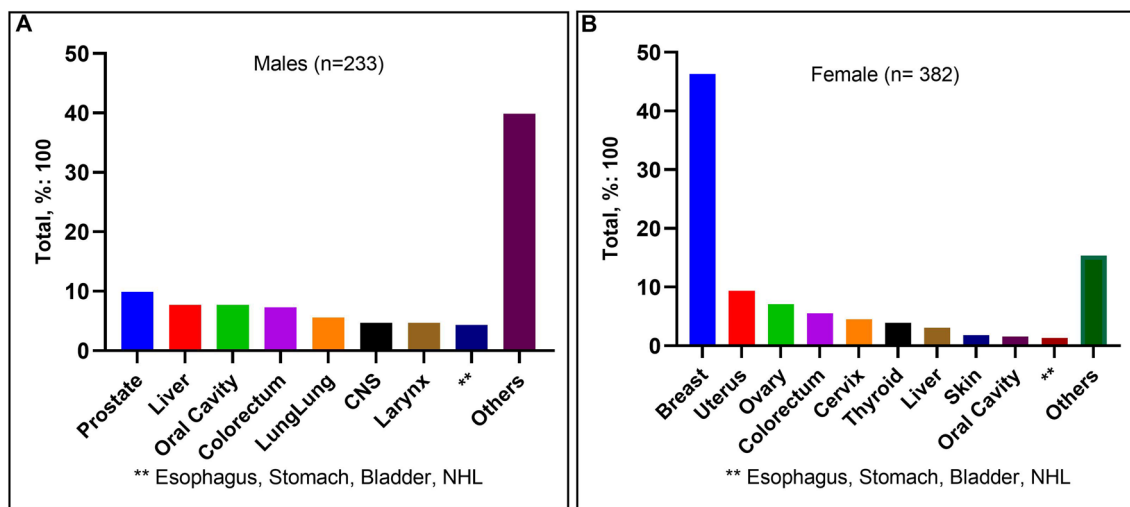


Fig. 3 Top 10 cancers among males and females in Islamabad

In the most populous province of Pakistan, Punjab, a total of 16,486 cancer cases were reported. Among males in Punjab, prostate cancer was the most common (19.6%), followed by liver cancer (7.3%), central nervous system cancer (7.3%), colorectal cancer (7.0%), lung cancer (7.4%), non-Hodgkin lymphoma (6.2%), bladder cancer (6.1%), and oral cavity cancer (6.0%). The prevalence of other types of

cancer was less than 5.0% (Fig. 4A). Breast cancer was the most prevalent cancer among females in Punjab (50.1%), followed by ovarian cancer (7.7%) and cervical cancer (5.2%). The prevalence of other types of cancer was less than 5.0% (Fig. 4B).

In Sindh province, 13,171 cancer cases were reported. Among male patients from Sindh, the most prevalent cancer

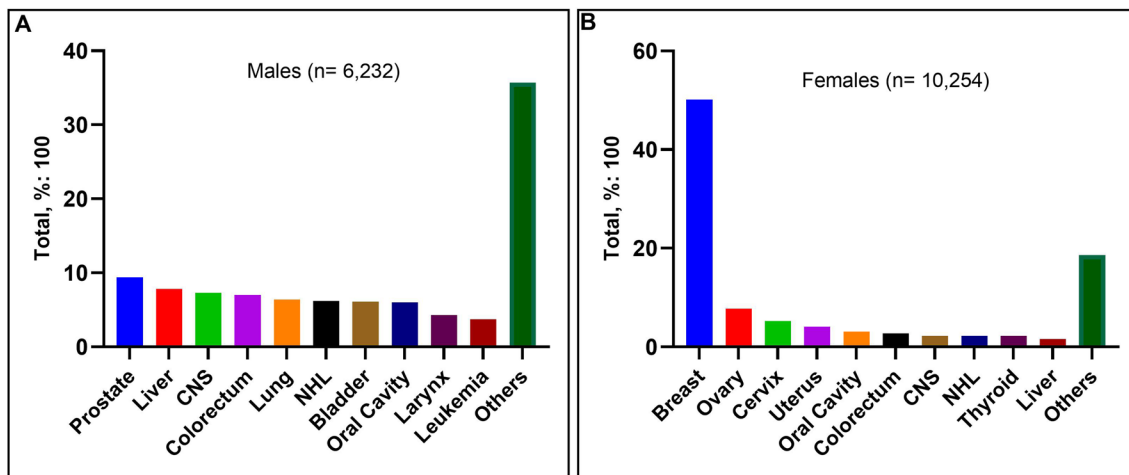


Fig. 4 Top 10 cancers among males and females in Punjab

was oral cavity cancer (30.9%), followed by lung cancer (7.5%), liver cancer (6.7%), and colorectal cancer (6.0%). Other types of cancer accounted for less than 5.0% (Fig. 5A). Breast cancer was the most prevalent cancer among females from Sindh (35.3%), followed by oral cavity cancer (10.9%), and cervical cancer (5.4%). Other types of cancer accounted for less than 5.0% (Fig. 5B).

A total of 6,578 cases were reported, with 3,033 cases among males and 3,545 cases among females. Among males in KPK, the most prevalent cancer was colorectal cancer (8.4%), followed by non-Hodgkin lymphoma (7.2%), central nervous system cancer (7.0%), prostate cancer (5.8%), leukemia (5.3%), and esophageal cancer (5.3%). The prevalence of other types of cancer was less than 5.0% (Fig. 6A). Among females in KPK, the most prevalent cancer was breast cancer (30.0%), followed by ovarian cancer (7.4%).

The prevalence of other types of cancer was less than 5.0% (Fig. 6B).

In Balochistan province, a total of 1,676 cases were reported, with 807 cases among males and 869 cases among females. Among males in Balochistan, the most prevalent cancer was oral cavity cancer (11.9%), followed by esophageal cancer (9.8%), colorectal cancer (7.6%), stomach cancer (6.9%), lung cancer (6.0%), and prostate cancer (5.6%). The prevalence of other types of cancer was less than 5.0% (Fig. 7A). Among females in Balochistan, the most prevalent cancer was breast cancer (30.7%), followed by esophageal cancer (12.6%), oral cavity cancer (7.2%), and ovarian cancer (7.0%). The prevalence of other types of cancer was less than 5.0% (Fig. 7B).

In Azad Jammu and Kashmir (AJK), a total of 529 cases were reported, with 218 cases among males and 311 cases

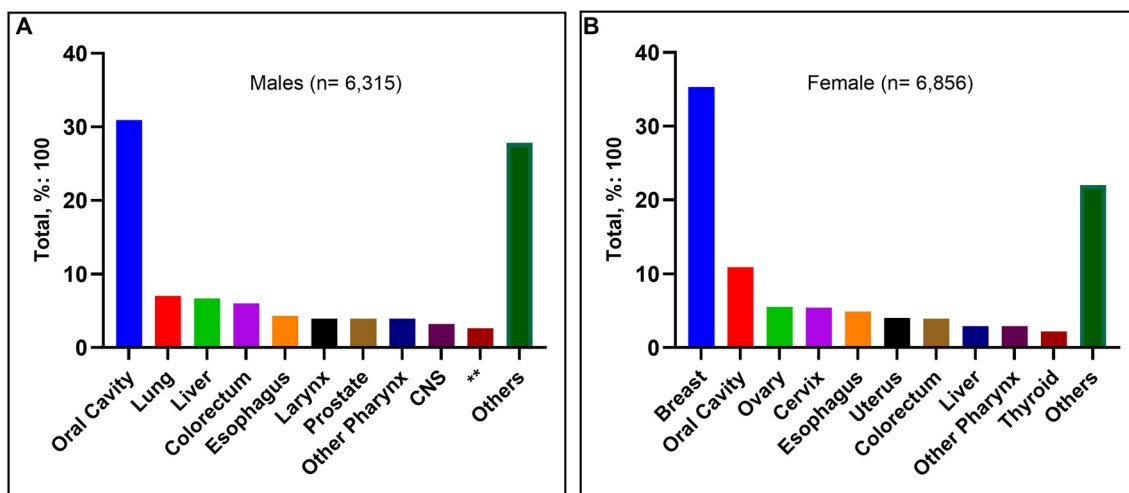


Fig. 5 Top 10 cancers among males and females in Sindh

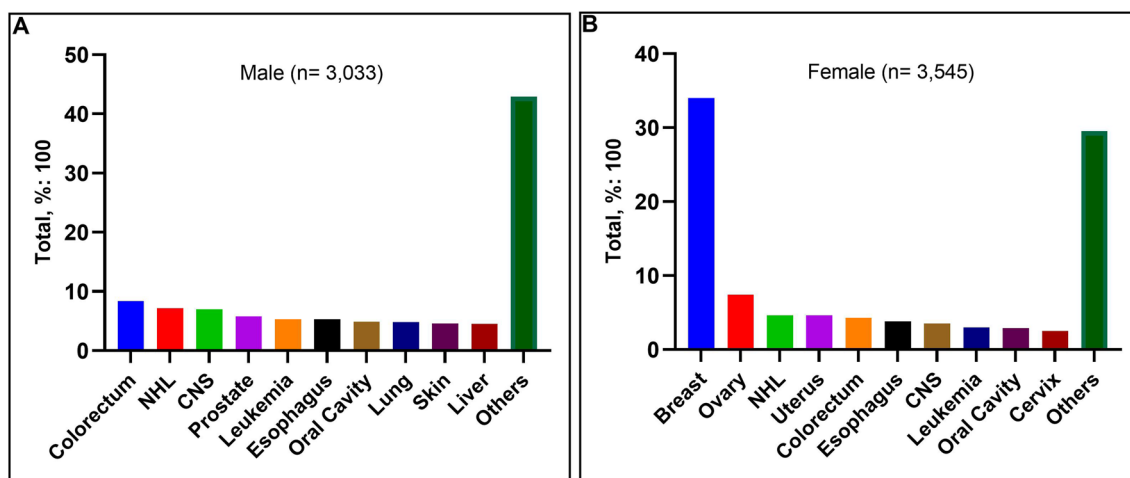


Fig. 6 Top 10 cancers among males and females in Khyber Pakhtunkhwa

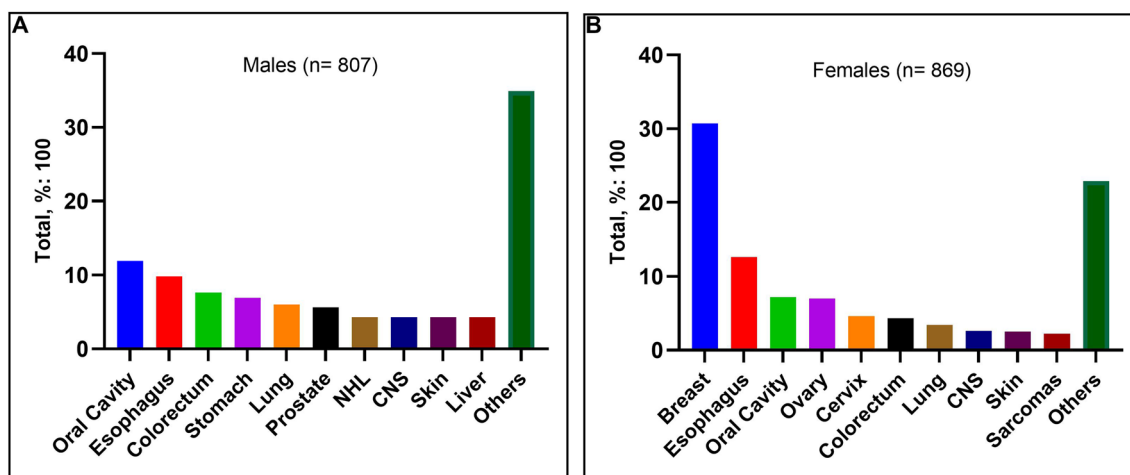


Fig. 7 Top 10 cancers among males and females in Balochistan

among females. Among males in AJK, the most prevalent cancer was bladder cancer (11.9%), followed by colorectal cancer (9.6%), central nervous system cancer (7.3%), prostate cancer (6.0%), oral cavity cancer (6.0%), non-Hodgkin lymphoma (5.0%), and stomach cancer (5.0%). The prevalence of other types of cancer was less than 5.0% (Fig. 8A). Among females in AJK, the most prevalent cancer was breast cancer (35.0%), followed by ovarian cancer (9.3%), and colorectal cancer (8.0%). The prevalence of other types of cancer was less than 5.0% (Fig. 8B).

In Gilgit-Baltistan, a total of 109 cases were reported, with 57 cases among males and 52 cases among females. Among males in Gilgit-Baltistan, the most prevalent cancer was non-Hodgkin lymphoma (10.5%), followed by oral cavity cancer (8.8%), bladder cancer (7.0%), prostate cancer (7.0%), and colorectal cancer (7.0%) (Fig. 9A). Among females in Gilgit-Baltistan, the most prevalent cancer was

breast cancer (19.2%), followed by central nervous system cancer (7.0%), ovarian cancer (7.0%), uterus cancer (7.0%), and skin cancer (7.0%) (Fig. 9B).

2.4 Comparing the Distribution of Patients with Previous Years

This study also examined cancer registry data from various regions in Pakistan between 2015 and 2019. The registry data showed that 2.0% of patients were registered in Islamabad, 44.0% in Punjab during 2015–2017, 38.0% in 2018, and 40.0% in 2019. Sindh accounted for 28.0% of registries during 2015–2017, 34.0% in 2018, and 32.0% in 2019. The Khyber Pakhtunkhwa (KPK) reported 13.0%, 16.0%, and 16.0% of registries, while Balochistan reported 7.0%, 4.0%, and 4.0% of registries (Fig. 10A).

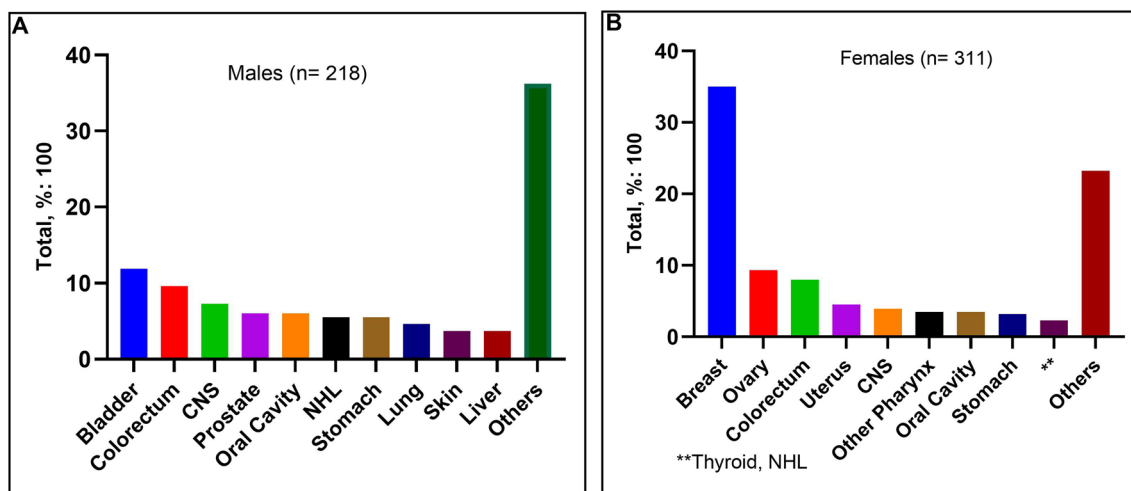


Fig. 8 Top 10 cancers among males and females in Azad Jammu and Kashmir

Fig. 9 Top 10 cancers among males and females in Gilgit Baltistan

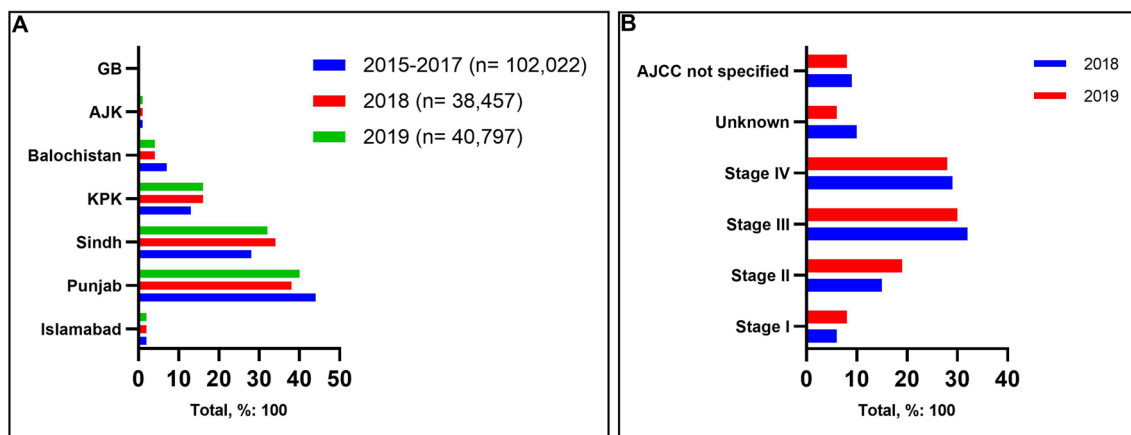
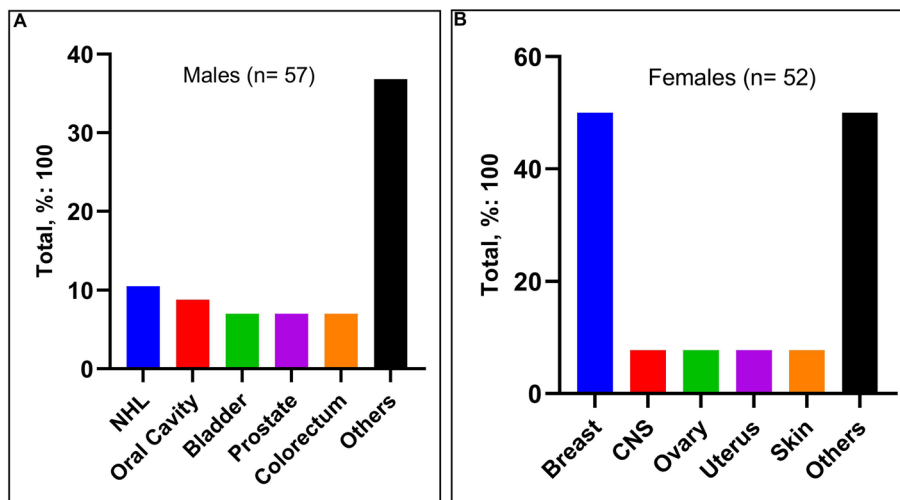


Fig. 10 A Top 10 Comparison of cancer registries from different regions of Pakistan from 2015–2019. B Comparison of cancer stages diagnosed in 2018 and 2019

All cancer cases were classified based on the TNM staging system established by the AJCC. The TNM system categorizes cancers as stages 0, I, II, III, IV, unknown, and AJCC not specified. Patients with unknown cancer stages may choose not to receive treatment or undergo further tests to determine the appropriate stage. If AJCC staging is not specified for a site, then AJCC staging is not available. In 2018, 32% of patients were at stage III, followed by 29% at stage IV, 15% at stage II, 10% unknown, 9.0% AJCC not specified, and 6.0% at stage I. In 2019, 30% of patients were at stage III, followed by 28% at stage IV, 19% at stage II, 8% at stage I, 9.0% AJCC not specified, and 6.0% unknown (Fig. 10B).

3 Discussion

Population-based cancer registries play a crucial role in monitoring and controlling cancer trends, considering the heterogeneity of populations in terms of genetics, demographics, and regions. The PAECR serves cancer patients from all regions of Pakistan and provides comprehensive descriptions and analyses of cancer patients in each province and region. Our study revealed that cancer incidence rates in Pakistan are heterogeneous, with Punjab showing a significantly higher incidence rate compared to other parts of the country. This is evident in the distribution of

registered patients, as shown in Fig. 11, which displays the number of cases from different divisions.

The findings of this study reveal important insights into the gender differential in primary cancer susceptibility. The higher number of female patients registered compared to males is consistent with previous studies that have reported a higher incidence of cancer in females [33]. Breast cancer was the most prevalent cancer among all patients, followed by oral cavity and colorectal cancers, which is in line with global cancer patterns [34]. These findings highlight the need for targeted interventions and screening programs for breast cancer in females, and oral cavity and colorectal cancers in both males and females.

The gender-specific analysis revealed differences in the types of cancers that were more common in males and females. Among males, oral cavity, colorectal, liver, prostate, and lung cancers were the most prevalent, while breast, ovarian, oral cavity, cervix, and uterus cancers were more common in females. These findings are consistent with the known gender-specific cancer types, where breast and prostate cancers are more common in females and males respectively [35]. However, it is worth noting that there were cases of breast cancer in males, although it is relatively uncommon. This highlights the importance of raising awareness about breast cancer in males and promoting early detection through regular screenings.

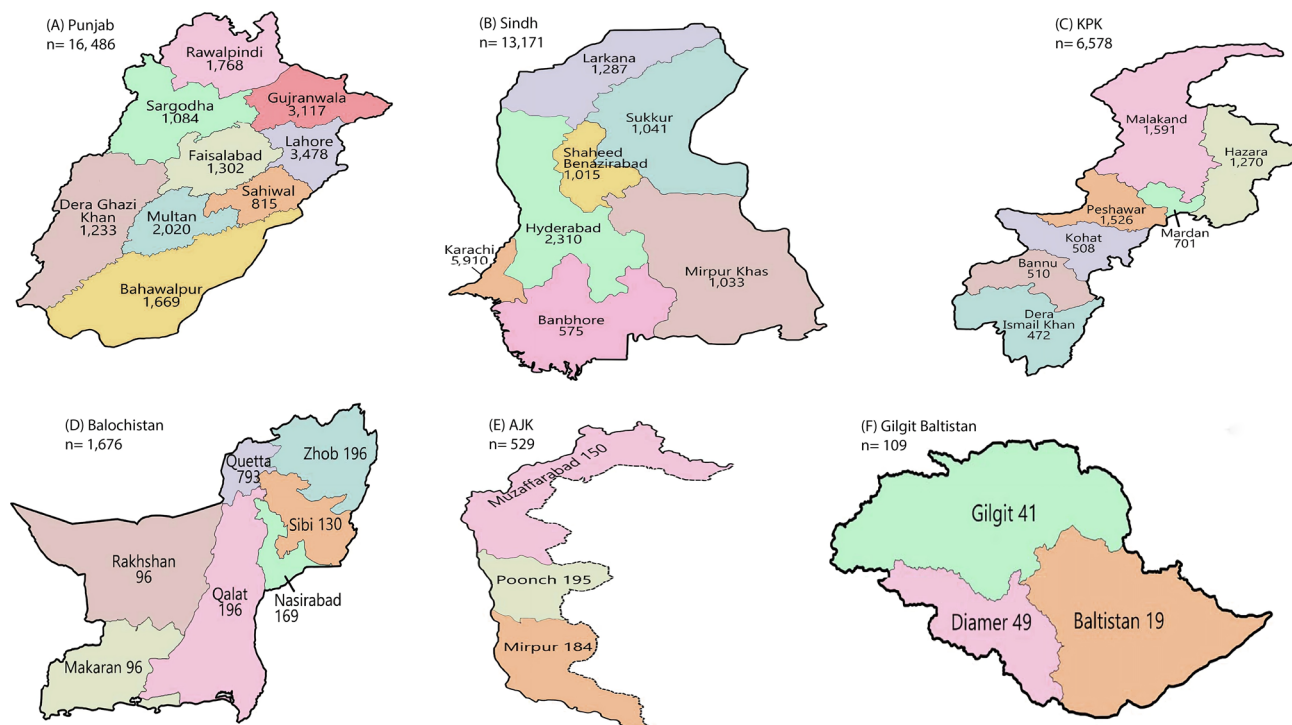


Fig. 11 Map representing cancer registries from different divisions of Pakistan

The lifetime risk of developing cancer was found to be higher in males compared to females, despite males having a shorter life expectancy. This suggests that males may be more susceptible to cancer overall, which is consistent with previous studies [33]. Furthermore, cancer mortality rates were higher in males compared to females, indicating that males may have poorer prognosis and outcomes after cancer diagnosis. This underscores the need for gender-specific strategies for cancer prevention, early detection, and treatment.

The findings of this study provide valuable insights into the prevalence of different types of cancer among various age groups. The study reveals that the most prevalent cancer types vary among different age groups, with central nervous system cancers being common in children, bone cancer in adolescents, breast cancer in adults, and breast and prostate cancers in senior citizens.

The high prevalence of breast cancer among females, accounting for 41.6% of all cancer cases, is consistent with global trends and underscores the significance of breast cancer as a major health concern [35]. The findings suggest that efforts to raise awareness about breast cancer, promote screening and early detection, and provide adequate healthcare resources for breast cancer prevention and treatment are crucial, especially among females.

Oral cavity cancer was also found to be prevalent in multiple age and gender groups, including males, females, adolescents, adults, and senior citizens. This highlights the need for effective strategies to prevent and manage oral cavity cancer, such as promoting oral hygiene practices, reducing tobacco and alcohol use, and increasing access to oral health care services.

Colorectal cancer was also identified as a common cancer in various age groups, including adolescents, adults, and middle-aged patients. This underscores the importance of promoting colorectal cancer screening and early detection strategies, as well as implementing lifestyle modifications to reduce risk factors associated with colorectal cancer, such as unhealthy diet and sedentary behavior.

The study also identified unique patterns of cancer prevalence among children and adolescents. Central nervous system cancers, leukemia, and Hodgkin's disease were found to be prevalent among children, while bone cancer and leukemia were common in adolescents, which is consistent with previous studies in children [36, 37], and adolescents [38, 39]. These findings highlight the need for targeted approaches to cancer prevention, screening, and treatment in these specific age groups, taking into consideration the unique biological, developmental, and psychosocial characteristics of children and adolescents.

The results of this study also shed light on the prevalence of cancer types in middle-aged and senior citizens. Middle-aged patients were found to have a higher prevalence of

breast cancer, oral cavity cancer, and cervical cancer, which emphasizes the importance of promoting gender-specific cancer screening and prevention strategies in this age group. Among senior citizens, breast cancer, prostate cancer, lung cancer, and bladder cancer were prominent, emphasizing the need for age-specific cancer screening and management strategies tailored to the health needs of elderly individuals.

The findings of this study shed light on the varying prevalence of different types of cancer among males and females in different provinces of Pakistan. Prostate cancer was found to be the most prevalent among males in Islamabad, Punjab, and KPK, while breast cancer was the most prevalent among females in Punjab, Sindh, KPK, Balochistan, Azad Jammu and Kashmir (AJK), and Gilgit-Baltistan. The findings from the cancer registry data provide important insights into the distribution of cancer cases across different regions of Pakistan and the staging of cancer at the time of diagnosis. Punjab had the highest proportion of cancer registries during the study period, followed by Sindh, KPK, and Balochistan. The TNM staging system, which categorizes cancer cases into different stages based on the extent of tumor growth, lymph node involvement, and metastasis, is a critical tool for determining the prognosis and appropriate treatment for cancer patients. In 2018 and 2019, a significant proportion of cancer cases were diagnosed at stage III and IV, which indicate advanced disease with potentially poorer outcomes. The high percentage of cases with unknown cancer stages and AJCC not specified in the registry data is concerning and may reflect limitations in the cancer reporting system or incomplete information in the registry.

It is essential to improve the quality and completeness of cancer registry data to accurately assess the burden of cancer and plan appropriate cancer control measures. The findings of this study have important implications for cancer control strategies in Pakistan. Early detection and screening programs should be prioritized to identify cancer cases.

The data obtained from the PAECR in 2019 were classified and coded using international standards, making them comparable to those from developed countries. The incidence dates and recording of multiple primary cancers were also in line with established protocols. However, it should be noted that the registry may not capture all incident cancers within Pakistani society, as it is expected to mature over time and data collection improves.

One limitation of the study is the lack of a centralized system for gathering mortality data in the region. This prevented the calculation of mortality-to-incidence ratios, which are important indicators of cancer outcomes. In order to assess changes in mortality rates over time, it will be necessary to obtain reliable mortality data from reliable sources.

Furthermore, the absence of a death registry also prevented the collection of cases that are identified solely through death certificates. This could potentially lead to an

underestimation of cancer cases, particularly those that are diagnosed late in the disease course and result in death.

Efforts should be made to improve the accuracy and completeness of cancer registry data in Pakistan. This may involve strengthening the data collection processes, implementing regular quality assurance measures, and establishing collaborations between different stakeholders to ensure that all incident cancers are captured in the registry. Additionally, the development of a centralized death registry could provide valuable information on cancer mortality rates and further enhance the understanding of cancer burden in Pakistan.

Despite these limitations, the data from the PAECR provide valuable insights into the cancer burden in Pakistan and can serve as a basis for formulating evidence-based cancer control strategies. It is important to continue monitoring and evaluating cancer trends in the country to inform effective cancer prevention, early detection, and treatment efforts. Collaborative efforts among researchers, healthcare providers, policymakers, and other stakeholders are essential to improve the quality of cancer registry data and advance cancer control efforts in Pakistan.

4 Conclusion

The lack of resources, epidemics, pandemics, and an increasing population in Pakistan have made it challenging to establish well-established systems in more developed regions. This comprehensive report represents the first examination of population-based cancer registration and incidence rates in 2019 in Pakistan. The population-based cancer registration in Pakistan appears to be lacking in both incidence and mortality statistics.

To establish regional cancer registries and collect data such as mortality and survival rates, various methods can be employed, including legislation and education of clinicians and the public. Cancer registration can become a priority in Pakistan if it is considered a health priority. Once the incidence and prevalence of cancer have been determined in larger populations, a continuum of care can be implemented. This includes addressing logistical issues, such as training oncologists, surgeons, pathologists, nurses, and public health officials, and building efficient hospitals. Furthermore, point-of-care testing can aid in better disease diagnosis, monitoring, and management. Policymakers are urged to take a progressive approach to cancer registration after reviewing this study, leading to positive and sustainable change.

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Author contribution The study was conducted by M.T., who designed the study, collected and analyzed the data, and wrote the manuscript. C.W. contributed to data visualization and provided critical review and approval of the final version of the manuscript.

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Data availability The author declares that the data that supports this study is available in the article. The data generated in the study is available at a reasonable request from the Co-responding author.

Declarations

Conflict of interest The authors have no competing interest.

Ethical approval This study was approved by Shanxi University.

Consent to participate Participant consent was not required in this registry-based study, as the data used were de-identified and anonymized, and did not contain personally identifiable information (PII). The study adhered to applicable regulations and ethical guidelines, and privacy and confidentiality of the data were maintained throughout the research process.

Consent for publication Not applicable.

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