Cancer burden and the contributions of risk factors in China: A systematic analysis for the Global Burden of Disease Study 2021

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Abstract

Background: As a populous country in the world, China ranks among the top in terms of new cancer cases and deaths worldwide. This study aims to provide a detailed evaluation of the cancer burden in China, considering the evolving social, economic, and environmental factors that may have influenced cancer incidence and mortality rates.

Methods: The cancer incidence, mortality, and the contributions of risk factors were estimated using data from the Global Burden of Disease Study (GBD) 2021. The number of new cases and deaths with their 95% uncertainty intervals (UIs) were analyzed. The trends of cancer age-standardized incidence rates (ASIR) from 1990 to 2021 and age-standardized death rates (ASDR) from 1980 to 2021 were estimated. Besides, risk factor contributions were also assessed.

Results: In 2021, the total burden of cancer in China comprised 13.66 million new cases (95% UI: 11.79 to 15.85 million) and 2.82 million deaths (95% UI: 2.35 to 3.36 million). In 2021, ASIR and ASDR of cancers were 790.2 (95% UI: 676.8–926.3) per 100,000 population and 137.5 (95% UI: 115.1–163.4) per 100,000 population, respectively. In 2021, tracheal, bronchus, and lung cancer showed the highest ASIR of 44.0 (95% UI: 35.4–53.3) per 100,000 population among site-specific tumors, followed by non-melanoma skin cancer (37.5 [95% UI: 32.4–42.7] per 100,000 population), colon and rectum cancer (31.4 [95% UI: 25.5–38.0] per 100,000 population), stomach cancer (29.1 [95% UI: 22.4–36.2] per 100,000 population), breast cancer (19.4 [95% UI: 15.0–24.3] per 100,000 population), esophageal cancer (15.0 [95% UI: 12–18.4] per 100,000 population), and liver cancer (9.5 [95% UI: 7.7–11.8] per 100,000 population). Besides, the ASDR of cancers decreased about 29.78% in males and 42.00% in females in the past forty years in China. Tracheal, bronchus, and lung cancer showed the highest ASIR (62.63 per 100,000 population) and ASDR (56.45 per 100,000 population) in males. Of note, 31.73% of all cancer deaths in China were digestive cancers in 2021. For level 1 risks in 2021, behavioral risks were linked to 73.57% of cancer deaths.

Conclusions: The disease burden of cancers remains a major public health concern in China. The ASIR increased from 1990 to 2021 and the ASDR decreased from 1980 to 2021 in cancers. Tracheal, bronchus, and lung cancer remain the most common types of cancer in China.

Keywords: Cancer burden; China; Global Burden of Disease Study; Incidence; Mortality; Disability-adjusted life years; Trend

Introduction

Cancer is the second most common cause of death worldwide, and predictions suggest that the global cancer burden will steadily increase for the next 20 years.[1] Efforts should be made to comprehensively assess the cancer burden, including the incidence, mortality, and disability-adjusted life year (DALY). Cancer epidemiological studies are crucial in informing and shaping government health policies, as they provide essential data for identifying risk factors, implementing population-level risk management strategies, developing cancer screening

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programs, and allocating resources for cancer prevention.[2,3]

In the past two to three decades, China has undergone significant transformations in its social, economic, and environmental landscapes. There has been a significant rise in the average life expectancy along with the economic growth. Additionally, there has been a change in the types of diseases that are affecting populations, shifting from communicable diseases to non-communicable diseases (NCDs), especially facing a significant cancer burden. Over the past 15 years, the cancer burden in China seemed to be transitioning to resemble that in high-income countries and the three leading fatal cancer types for both sexes was tracheal, bronchus, and lung (TBL) cancer, liver cancer, and stomach cancer.[4] Meanwhile, in the past two decades, China has put significant effort into controlling and preventing cancer, such as the Action Plan to Improve the Quality of Oncology Diagnosis and Treatment from 2021 to 2024 and Implementation Plan for Cancer Prevention and Control Action (2023–2030), to deal with the rising cancer burden during the rapid economic and social development.[5,6] A cancer registration system has been established in China, covering a population of 1.407 billion, to provide data support for cancer research and prevention and control. Therefore, comprehensive assessments of cancer burden will provide useful information for improving the tumor quality control management system in China. Especially after China experienced the coronavirus disease 2019 (COVID-19) pandemic, it appears that cancer patients experience worsened symptoms and an increased risk of death when they contract the virus.[7]

The Global Burden of Disease (GBD) 2021 study enables standardized quantification of cancer burden across various dimensions, including incidence, mortality, and DALYs, while evaluating the contributions of modifiable risk factors. In China, approximately 45% of cancer deaths are attributable to modifiable factors, such as smoking, air pollution, and dietary. A previous studies have highlighted the national prevalence of these risks; however significant gaps persist in characterizing their temporal dynamics and heterogeneity across cancer types, age groups, and sex. Existing analyses often aggregate risk-attributable burden across all cancers, obscuring type-specific variations in preventable fractions.[8,9] Thus, evidence remains limited regarding systematic quantification of how these associations between risk factor and cancer have evolved in response to China's rapid urbanization, population aging, and lifestyle transitions since 2010. Furthermore, China's rapidly aging population, the largest globally, significantly amplifies the cancer burden. This demographic shift underscores the critical need to understand not only the overall trends in cancer burden and risk factor contributions but also how these dynamics manifest across different age groups.[10] Therefore, this study utilized data from GBD 2021 to estimate the trends in cancer incidence, mortality, and the contribution of risk factors in China. By providing a comprehensive analyses of the cancer burden in China and modifiable risk factors, this study aims to inform policy development and guide efforts to enhance cancer prevention strategies.

Methods

GBD source

The GBD is a comprehensive research initiative led by the Institute for Health Metrics and Evaluation (IHME) that systematically quantifies health loss from diseases, injuries, and risk factors across populations worldwide. Chinese cancers data regarding the incidence, mortality and the contribution of risk factors were obtained from the GBD. The age-standardized incidence rates (ASIRs) in GBD 2021 cover the period from 1990 to 2021, whereas the age-standardized deaths rates (ASDRs) span from 1980 to 2021. Extending the ASDRs analysis to 1980 enables capturing long-term mortality trends and is critical for identifying shifts in cancer patterns associated with socioeconomic transitions that accelerated in China during the 1980s. Thus, the trends of cancer ASIRs from 1990 to 2021 and ASDRs from 1980 to 2021 were estimated in this study. We also estimated the ASIRs and ASDRs of 34 cancer types. The GBD study integrates cancer registration data from the National Central Cancer Registry (NCCR) of China. To address significant regional heterogeneity within China's cancer data, such as variations in reporting systems and temporal changes in underreporting rates, systematic corrections were applied. This involved modeling the data using spatiotemporal Gaussian process regression (ST-GPR), estimating missing report rates based on the Health Access and Quality Index (HAQ) and cause of death ensemble modeling (CODEm), and leveraging the mortality-to-incidence ratio (MIR) to back-predict historical incidence trends. This comprehensive analysis relies on the most up-to-date epidemiological data and utilizes standardized methods for data collection and analysis. The data can be accessed through the Global Health Data Exchange query tool (http://ghdx.healthdata.org/gbd-results-tool), allowing users to explore the data based on region, gender, country, and specific risk factors. Furthermore, GBD 2021 provides essential statistical information across 23 age categories, spanning from birth to ages equal to or greater than 95 years, encompassing data for males, females, and both genders. Cancers were defined based on the International Classification of Diseases, Tenth Revision (ICD-10). The current GBD estimation is based on the methodology described in the latest GBD study.[11,12] A brief overview of the input data and methodological flowchart for the GBD estimate was presented in Supplementary Figure 1, http://links.lww.com/CM9/C659.

Estimates

The GBD 2021 Collaborators modeled incidence and deaths estimates for male and female across all age groups.[13] The CODEm was applied to estimate cause-specific mortality. The GBD team developed the DisMod-MR 2.1 software, a Bayesian meta-regression tool, to conduct incidence estimations through an analytical cascade process. Information about bias correction and other adjustments made for each specific disorder can be found in the GBD 2019 capstone report.[14] DALYs, a summary measure of total health loss, were computed by adding years of live lost (YLLs) and years lived with disability

(YLDs) for each cause. Thus, we also mainly used DALYs to characterize the burden caused by cancer-related risk factors. The GBD comparative risk assessment (CRA) framework was utilized to calculate the exposure of risk factors linked to cancers and their resulting disease burden. The population attributable fraction (PAF) of YLLs and YLDs was determined for each risk factor by taking into account the distribution of exposures across different ages, genders, and years, as well as the relative risk associated with each level of exposure. Using the Bayesian age-period-cohort (BAPC) package in R software (R 4.2.3, R Foundation for Statistical Computing, Vienna, Austria), the projected disease incidence for the year 2041, based on available data, is averaged and applied to population projections provided by the United Nations for each country, allowing for forward projections of the number of cases and age standardized rate (ASR) to 2041.[15]

Statistical analysis

In accordance with the GBD framework, 95% uncertainty intervals (UIs) for all estimates by averaging the data from 1000 draws, with the lower and upper bounds of the 95% UIs determined by the 2.5th and 97.5th ranked values among all 1000 draws.[16] All statistical analyses were carried out using R software. This study utilized data from the GBD study, which has received ethical approval from the Institutional Review Board at the University of Washington, and is publicly accessible. The GBD study analyses adhere to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) guidelines.[17]

Results

Burden of total cancers in China

In 2021, the total burden of cancer in China included 13.66 million new cases (95% UI: 11.79 to 15.85 million), 2.82 million deaths (95% UI: 2.35 to 3.36 million), and 71.22 million DALYs (95% UI: 59.32 to 85.19 million). This accounted for 20.55% of global new cases, 28.50% of global deaths, and 28.12% of global DALYs. Cancer deaths and DALYs in China were significantly higher than in India, the United Kingdom, and the United States of America [Supplementary Figure 2, http://links.lww.com/CM9/C659]. In 2021, cancers accounted for 24.07% (95% UI: 22.74–25.29%) of total deaths and 17.7% (95% UI: 15.21–20.2%) of total DALYs in China. In 2021, ASIR and ASDR of cancers were 790.2 (95% UI: 676.8–926.3) per 100,000 population and 137.5 (95% UI: 115.1–163.4) per 100,000 population, respectively. In 2021, TBL cancer showed the highest ASIR of 44.0 (95% UI: 35.4–53.3) per 100,000 population among site-specific tumors, followed by non-melanoma skin cancer (ASIR: 37.5 [95% UI: 32.4–42.7] per 100,000 population), colon and rectum cancer (ASIR: 31.4 [95% UI: 25.5–38.0] per 100,000 population), stomach cancer (ASIR: 29.1 [95% UI: 22.4–36.2] per 100,000 population), breast cancer (ASIR: 19.4 [95% UI: 15.0–24.3] per 100,000 population), esophageal cancer (ASIR: 15.0 [95% UI: 12.0–18.4] per 100,000 population), and liver cancer (ASIR: 9.5 [95% UI: 7.7–11.8] per 100,000 population). Meanwhile, TBL cancer showed the highest ASDR of 39.0 (95% UI: 31.4–47.1) per 100,000 population among site-specific tumors, followed by stomach cancer (ASDR: 21.5 [95% UI: 16.7–26.6] per 100,000 population), esophageal cancer (ASDR: 14.1 [95% UI: 11.4–17.2] per 100,000 population), colon and rectum cancer (ASDR: 13.6 [95% UI: 11.1–16.3] per 100,000 population), liver cancer (ASDR: 8.4 [95% UI: 6.8–10.3] per 100,000 population), and pancreatic cancer (ASDR: 5.7 [95% UI: 4.6–6.9] per 100,000 population) [Table 1].

In 2021, 31.73% of all cancer deaths in China were digestive cancers. Figure 1 shows the number of new cases of various types of cancer in males and females, as well as the corresponding proportions. In 2021, females showed higher ASIR than males (1014.80 per 100,000 population for females *vs.* 599.70 per 100,000 population for males), while males showed higher ASDR than females (190.67 per 100,000 population for males *vs.* 93.72 per 100,000 population for females). In females, breast cancer showed the highest ASIR (37.00 per 100,000 population) and TBL cancer showed the highest ASDR (24.42 per 100,000 population). While, TBL cancer showed the highest ASIR (62.63 per 100,000 population) and ASDR (56.45 per 100,000 population) in males. It is worth noting that digestive cancer was a significant contributor to cancer-related deaths in China in 2021 [Supplementary Figure 3, http://links.lww.com/CM9/C659]. From 1990 to 2021, females showed a higher number of new cases and ASIR than males, with ASIR showing a stable trend in both sexes. In contrast, from 1980 to 2021, males showed greater number of deaths and higher ASDR than females, and ASDR shows a declining trend in both females and males and the ASDR of cancers decreased about 29.78% in males and 42.00% in females in the past forty years in China [Figure 2].

Significant sex-specific differences were observed in the age distribution of new cancer cases and deaths. In 2021, the peak number of new cancer cases in specific age groups was observed in females aged 50 to 54 years and males aged 65 to 69 years. Before the age of 60 years, the number of new cancer cases in females were higher than that in males, while from the age of 60 to 64 years, the situation became the opposite [Figure 3A]. The new cancer cases were more pronounced among women before the age of 50 years. The number of deaths peaked in individuals aged 70 to 74 years for both males and females, and the number of deaths among males was approximately twice that of females [Figure 3B].

Burden of specific cancers in China

In order to identify patterns and trends in both incidence and mortality rates for specific cancer, we conducted an in-depth analysis of the trends in ASIR and ASDR across various types of cancer stratified by sex. Prostate cancer and breast cancer primarily affect men and women, respectively, and the ASIRs for both are increasing annually. ASDR exhibited decreasing or stable trends for most cancers. However, a gradual increase in ASDR was observed for certain cancers, such as multiple myeloma and neuroblastoma and other peripheral nerve cell tumors. ASIR showed significant or modest increases for some cancers,

Table 1: The number of new cases and death cases and ASIR/ASDR in China.

Items	Number of new cases		ASIR per 100,000 population		Number of cancer-associated death		ASDR per 100,000 population	
	1990	2021	1990	2021	1980	2021	1980	2021
Neoplasms	7,818,410 (6,478,326–9,545,530)	13,664,748 (11,787,026–15,848,005)	718.7 (608.7–842.6)	790.2 (676.8–926.3)	1,304,454 (1,106,050–1,547,919)	2,817,757 (2,347,976–3,360,869)	209.5 (179.2–246.9)	137.5 (115.1–163.4)
Bladder cancer	35,813 (25,632–42,116)	105,791 (83,242–136,670)	4.7 (3.4–5.5)	5.1 (4.1–6.6)	17,299 (12,734–21,344)	45,114 (36,263–57,335)	3.6 (2.7–4.3)	2.3 (1.9–2.9)
Kidney cancer	16,232 (14,235–18,287)	65,799 (53,687–79,743)	1.8 (1.6–2.0)	3.3 (2.7–4.0)	6852 (5513–8319)	24,867 (20,361–29,828)	1.1 (0.9–1.3)	1.2 (1.0–1.5)
Prostate cancer	13,754 (10,154–17,772)	88,601 (63,194–120,965)	2.0 (1.5–2.6)	4.2 (3–5.7)	7332 (5332–9405)	37,364 (27,851–50,366)	1.8 (1.3–2.2)	2.0 (1.5–2.7)
Brain and CNS	47,364 (34,333–59,067)	105,541 (81,401–133,528)	4.7 (3.4–5.9)	6.1 (4.8–7.7)	30,758 (21,914–40,546)	68,911 (52,055–88,280)	4.0 (2.9–5.3)	3.6 (2.7–4.6)
NPNC	665 (457–958)	2084 (1548–2569)	0.1 (0.0–0.1)	0.1 (0.1–0.2)	199 (147–287)	1070 (792–1298)	0.0 (0.0–0.0)	0.1 (0.1–0.1)
Breast cancer	86,709 (70,225–105,273)	402,794 (312,117–505,644)	9.1 (7.4–11.0)	19.4 (15.0–24.3)	34,575 (26,633–44,621)	91,484 (71,739–113,711)	5.3 (4.1–6.7)	4.4 (3.5–5.5)
Cervical cancer	57,843 (46,321–71,402)	132,788 (95,959–172,600)	5.8 (4.7–7.2)	6.7 (4.8–8.7)	33,646 (25,747–42,464)	49,841 (36,878–64,386)	5.0 (3.9–6.2)	2.4 (1.8–3.1)
Ovarian cancer	19,998 (14,086–26,191)	41,236 (30,302–54,549)	2.0 (1.5–2.6)	2.0 (1.5–2.7)	8487 (5942–12,838)	25,144 (18,526–32,923)	1.3 (0.9–1.9)	1.2 (0.9–1.5)
Uterine cancer	26,311 (18,116–33,312)	105,791 (83,241–136,669)	2.8 (2.0–3.5)	3.3 (2.5–4.7)	9844 (6062–13,644)	13,599 (9926–18,596)	1.5 (1.0–2.1)	0.6 (0.5–0.9)
Testicular cancer	1,839 (1,521–2,183)	6696 (5181–8656)	0.2 (0.1–0.2)	0.4 (0.3–0.5)	658 (501–838)	1245 (962–1580)	0.1 (0.1–0.1)	0.1 (0.1–0.1)
Colon and rectum cancer	158,389 (135,419–182,577)	658,321 (531,995–798,063)	19.0 (16.5–21.8)	31.4 (25.5–38.0)	96,171 (71,066–121,891)	275,129 (223,379–330,960)	16.7 (12.4–21.0)	13.6 (11.1–16.3)
Esophageal cancer	207,495 (172,674–241,459)	320,805 (256,102–394,756)	24.8 (20.7–28.7)	15.0 (12.0–18.4)	180,283 (144,651–219,979)	296,443 (236,648–362,831)	29.8 (23.8–36.0)	14.1 (11.4–17.2)
GBTC	170,78 (13,003–21,744)	51,720 (35,618–66,848)	2.2 (1.7–2.8)	2.5 (1.7–3.2)	13,288 (9,255–18,441)	37,834 (26,653–49,262)	2.4 (1.7–3.3)	1.9 (1.3–2.4)
Liver cancer	96,434 (80,971–113,769)	196,637 (158,273–243,558)	10.6 (8.9–12.4)	9.5 (7.7–11.8)	92,343 (69,484–118,574)	172,068 (139,621–212,496)	13.7 (10.4–17.5)	8.4 (6.8–10.3)
Pancreatic cancer	37,818 (31,791–44,068)	118,665 (94,623–144,663)	4.5 (3.8–5.3)	5.6 (4.5–6.8)	28,824 (21,257–40,082)	119,602 (95,654–145,218)	4.8 (3.6–6.6)	5.7 (4.6–6.9)
Stomach cancer	407,471 (337,565–477,569)	611,799 (471,966–765,562)	48 (40.2–56.7)	29.1 (22.4–36.2)	343,519 (278,117–413,150)	445,013 (344,736–555,834)	56.5 (46.2–67.6)	21.5 (16.7–26.6)
Leukemia	76,204 (58,312–90,958)	105,667 (75,276–132,237)	7.1 (5.5–8.6)	7.2 (4.9–9.1)	64,275 (47,458–82,514)	58,904 (43,626–74,039)	7.5 (5.6–9.5)	3.4 (2.5–4.3)
Hodgkin lymphoma	4,746 (2,015–6,561)	4211 (2542–5542)	0.5 (0.2–0.7)	0.2 (0.1–0.3)	4344 (1831–6255)	2443 (1507–3232)	0.6 (0.3–0.9)	0.1 (0.1–0.2)
Non–Hodgkin lymphoma	31,216 (26,893–37,952)	110,924 (86,934–135,200)	3.3 (2.9–4.0)	5.5 (4.4–6.7)	20,944 (16,648–25,761)	42,857 (33,553–51,712)	3.0 (2.4–3.7)	2.1 (1.7–2.6)
Larynx cancer	15,434 (12,624–18,174)	38,905 (30,370–49,486)	1.8 (1.5–2.1)	1.8 (1.4–2.3)	10,150 (7635–12,979)	19,800 (15,580–25,023)	1.7 (1.3–2.1)	0.9 (0.7–1.2)
Eye cancer	1,496 (937–2,021)	3729 (2065–4830)	0.2 (0.1–0.2)	0.3 (0.1–0.4)	603 (344–841)	693 (369–912)	0.1 (0.1–0.1)	0.0 (0.0–0.1)
Lip and oral cavity cancer	14,687 (12,390–16,909)	56,359 (45,178–69,804)	1.7 (1.5–1.9)	2.7 (2.2–3.3)	7281 (5880–9251)	23,882 (18,972–29,681)	1.2 (1.0–1.5)	1.2 (0.9–1.4)
MABAC	6,382 (4,178–11,228)	25,938 (16,243–34,274)	0.7 (0.4–1.1)	1.4 (0.9–1.9)	5339 (3887–8623)	18,085 (11,288–24,126)	0.8 (0.5–1.2)	0.9 (0.6–1.2)
Soft tissue and other extraosseous sarcomas	5,804 (4,085–7,530)	9227 (6352–13,046)	0.6 (0.4–0.8)	0.5 (0.3–0.7)	3480 (2263–4608)	4635 (3208–6510)	0.5 (0.3–0.7)	0.2 (0.2–0.3)
Mesothelioma	1,155 (970–1,372)	3046 (2454–3714)	0.1 (0.1–0.2)	0.1 (0.1–0.2)	835 (665–1101)	3011 (2427–3665)	0.1 (0.1–0.2)	0.1 (0.1–0.2)
Multiple myeloma	1,693 (1,154–3,360)	17,250 (11,017–22,663)	0.2 (0.1–0.4)	0.8 (0.5–1.1)	1182 (725–2301)	12,984 (8,448–17,114)	0.2 (0.1–0.4)	0.6 (0.4–0.8)
Nasopharynx cancer	44,864 (38,023–51,827)	65,934 (53,272–81,431)	4.6 (3.9–5.4)	3.4 (2.8–4.2)	30,166 (23,929–36,071)	31,321 (25,467–38,381)	4.4 (3.5–5.2)	1.5 (1.2–1.8)
Malignant skin melanoma	3,250 (2,093–4,089)	13,438 (7,198–17,979)	0.4 (0.2–0.5)	0.7 (0.4–0.9)	1985 (1205–2827)	5373 (2849–7106)	0.3 (0.2–0.4)	0.3 (0.1–0.4)
Non–melanoma skin cancer	39,492 (33,276–45,762)	791,868 (674,907–907,771)	4.7 (4.0–5.4)	37.5 (32.4–42.7)	3944 (3146–5094)	16,576 (13,017–20,670)	0.8 (0.6–1.0)	0.9 (0.7–1.1)
Other malignant neoplasms	41,387 (27,527–51,720)	106,746 (82,738–134,939)	4.5 (3–5.6)	5.6 (4.3–7.0)	26,190 (16,835–34,750)	39,756 (31,077–49,408)	4.0 (2.6–5.2)	2.0 (1.6–2.5)
Other neoplasms	6,007,404 (4,715,211–7,715,301)	8,335,340 (6,704,328–10,316,552)	511.0 (406.4–635.8)	531.3 (425.7–661.0)	866 (395–1786)	4,778 (2,822–8,796)	0.1 (0.1–0.3)	0.3 (0.1–0.5)
Other pharynx cancer	5,074 (4,142–6,175)	12,063 (9,529–15,280)	0.6 (0.5–0.7)	0.6 (0.4–0.7)	3089 (2370–4031)	5881 (4692–7407)	0.5 (0.4–0.6)	0.3 (0.2–0.3)
Thyroid cancer	12,157 (9,714–14,406)	48,105 (38,695–60,068)	1.2 (1.0–1.5)	2.5 (2.0–3.1)	2937 (2353–3600)	7692 (6123–9429)	0.5 (0.4–0.6)	0.4 (0.3–0.5)
Tracheal, bronchus, and lung cancer	274,752 (234,741–315,112)	934,704 (750,040–1,136,938)	33.1 (28.5–37.8)	44.0 (35.4–53.3)	212,770 (170,020–268,844)	814,364 (652,636–987,795)	35.6 (28.9–44.6)	39.0 (31.4–47.1)

Data are presented as estimated and 95% UI. ASDR: Age standardized death rate; ASIR: Age standardized incidence rate; CNS: Central nervous system cancer; GBTC: Gallbladder and biliary tract cancer; NPNC: Neuroblastoma and other peripheral nervous cell tumors; MABAC: Malignant neoplasm of bone and articular cartilage; UI: Uncertainty interval. Other neoplasms included: (1) Benign and *in situ* intestinal neoplasms, (2) Myelodysplastic, myeloproliferative, and other hematopoietic neoplasms, (3) Benign and *in situ* cervical and uterine neoplasms, and (4) Other benign and *in situ* neoplasms.

	Incidence, N	Precentage	ASIR
Other neoplasms	2,464,479	44.10%	282.12
Tracheal, bronchus, and lung cancer	622,760	11.14%	62.63
Stomach cancer	446,434	7.99%	44.48
Non-melanoma skin cancer	433,699	7.94%	43.66
Colon and rectum cancer	419,012	7.50%	42.24
Esophageal cancer	249,647	4.47%	24.78
Liver cancer	143,788	2.57%	14.34
Prostate cancer	88,601	1.59%	9.34
Bladder cancer	85,319	1.53%	9.05
Non-Hodgkin lymphoma	72,382	1.30%	7.38
Pancreatic cancer	72,280	1.29%	7.29
Other malignant neoplasms	64,390	1.15%	6.86
Leukemia	62,564	1.12%	8.51
Brain and central nervous system cancer	54,097	0.97%	6.33
Nasopharynx cancer	49,872	0.89%	5.16
Kidney cancer	46,529	0.83%	4.80
Lip and oral cavity cancer	41,648	0.75%	4.13
Larynx cancer	32,510	0.58%	3.12
Gallbladder and biliary tract cancer	27,797	0.50%	2.89
Thyroid cancer	20,189	0.36%	2.11
Breast cancer	16,956	0.30%	1.60
Malignant neoplasm of bone and articular cartilage	15,799	0.28%	1.78
Multiple myeloma	10,772	0.19%	1.06
Other pharynx cancer	9802	0.18%	0.93
Malignant skin melanoma	6972	0.12%	0.73
Testicular cancer	6696	0.12%	0.82
Soft tissue and other extraosseous sarcomas	5625	0.10%	0.63
Hodgkin lymphoma	2606	0.05%	0.29
Eye cancer	1863	0.03%	0.27
Mesothelioma	1782	0.03%	0.18
Neuroblastoma and other peripheral nervous cell tumors	1294	0.02%	0.18
All sites	5,588,169	100%	599.70

Males Females

	Incidence, N	Precentage	ASIR
Other neoplasms	5,870,861	72.69%	804.07
Breast cancer	385,838	4.78%	37.00
Non-melanoma skin cancer	348,168	4.31%	32.57
Tracheal, bronchus, and lung cancer	311,944	3.86%	28.16
Colon and rectum cancer	239,309	2.96%	21.87
Stomach cancer	165,365	2.05%	15.23
Cervical cancer	132,788	1.64%	13.37
Uterine cancer	72,019	0.89%	6.65
Esophageal cancer	71,158	0.88%	6.40
Liver cancer	52,848	0.65%	4.89
Brain and central nervous system cancer	51,444	0.64%	5.96
Pancreatic cancer	46,386	0.57%	4.18
Leukemia	43,104	0.53%	5.92
Other malignant neoplasms	42,357	0.52%	4.61
Ovarian cancer	41,236	0.51%	4.05
Non-Hodgkin lymphoma	38,541	0.48%	3.77
Thyroid cancer	27,915	0.35%	2.87
Gallbladder and biliary tract cancer	23,923	0.30%	2.17
Bladder cancer	20,472	0.25%	1.89
Kidney cancer	19,271	0.24%	1.95
Nasopharynx cancer	16,062	0.20%	1.69
Lip and oral cavity cancer	14,711	0.18%	1.38
Malignant neoplasm of bone and articular cartilage	10,139	0.13%	1.07
Multiple myeloma	6478	0.08%	0.59
Malignant skin melanoma	6463	0.08%	0.64
Larynx cancer	6394	0.08%	0.58
Soft tissue and other extraosseous sarcomas	3602	0.04%	0.36
Other pharynx cancer	2261	0.03%	0.21
Eye cancer	1865	0.02%	0.30
Hodgkin lymphoma	1605	0.02%	0.18
Mesothelioma	1264	0.02%	0.12
Neuroblastoma and other peripheral nervous cell tumors	790	0.01%	0.12
All sites	8,076,580	100%	1014.80

Figure 1: Estimated new cases number and proportion of cancer in males and females in China based on GBD 2021. ASIR: Age standardized incidence rate; GBD: Global Burden of Disease.

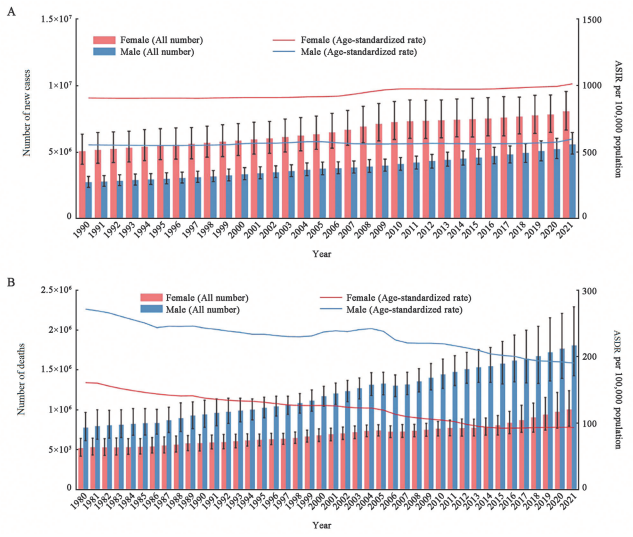


Figure 2: Trends in the number of new cancer cases and cancer-related deaths as well as ASIR and ASDR, in China based on GBD. (A) Trend of number of new cancer cases and ASIR in China from 1990 to 2021. (B) Trend of number of cancer-related deaths and ASDR in China from 1980 to 2021. ASDR: Age standardized death rate; ASIR: Age standardized incidence rate; GBD: Global Burden of Disease.

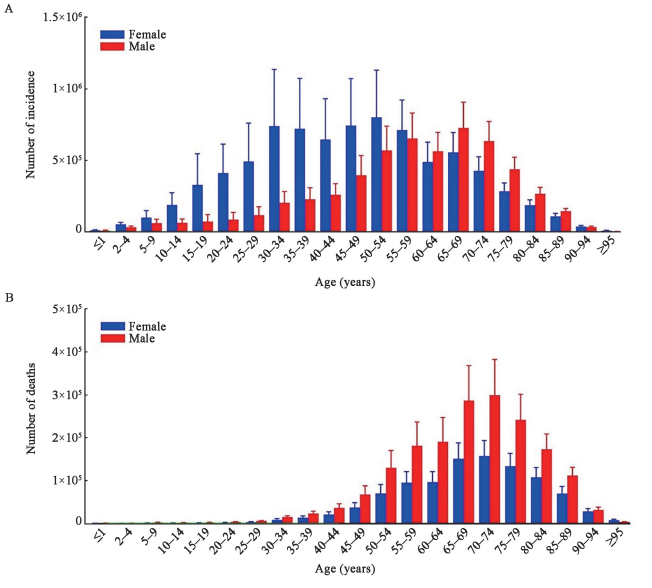


Figure 3: The cancers count of different age groups and gender in China based on GBD. (A) Number of cancer incidence by age groups from 1990 to 2021. (B) Number of cancer deaths by age groups from 1980 to 2021. ASDR: Age standardized death rate; ASIR: Age standardized incidence rate; GBD: Global Burden of Disease.

such as brain and central nervous system cancer, breast cancer, non-hodgkin lymphoma, colon and rectum cancer, kidney cancer, and multiple myeloma [Supplementary Figure 4, http://links.lww.com/CM9/C659]. In contrast, ASIR demonstrated a decreasing trend for liver cancer, stomach cancer, and esophageal cancer [Supplementary Figure 4, http://links.lww.com/CM9/C659].

Furthermore, given the substantial disease burden of liver cancer in China and its distinct, well-characterized etiological profile dominated by hepatitis B, coupled with the pronounced heterogeneity across leukemia subtypes and their significant impact on pediatric and adult populations, we undertook comprehensive subgroup analyses focusing on these two malignancies. In liver cancer subgroup, liver cancer due to hepatitis B showed the highest ASIR (5.7 per 100,000 population), followed by hepatitis C (1.8 per 100,000 population), alcohol use (0.9 per 100,000 population), non-alcoholic steatohepatitis (NASH) (0.5 per 100,000 population), other causes (0.5 per 100,000 population), and hepatoblastoma (0.1

per 100,000 population) in 2021. Meanwhile, the ASDR showed the same trend. In leukemia subgroup, acute lymphoid leukemia showed the highest ASIR (3.4 per 100,000 population), followed by chronic lymphoid leukemia (1.4 per 100,000 population), acute myeloid leukemia (1.0 per 100,000 population), other leukemia (0.9 per 100,000 population), and chronic myeloid leukemia (0.2 per 100,000 population). While, acute lymphoid leukemia showed the highest ASDR (1.4 per 100,000 population), followed by acute myeloid leukemia (0.9 per 100,000 population), and other leukemia (0.6 per 100,000 population) [Supplementary Table 1, http://links.lww.com/CM9/C659]. The trends in both ASIR and ASDR by sex in liver cancer and leukemia subgroups are displayed in Supplementary Figure 5, http://links.lww.com/CM9/C659.

Cancers burden by risk factors

In accordance with the hierarchical structure of the GBD risk framework (where Level 2 risks are nested within Level 1 categories, and Level 3/4 risks provide further granularity within Level 2), we first examined the contributions of major Level 1 risk categories to cancer mortality in China for 2021, finding behavioral risks linked to 73.57% of cancer deaths, environmental and occupational risks to 18.34%, and metabolic risks to 8.09% [Table 2]. To identify specific modifiable factors, we then analyzed Level 2 risks, revealing eleven risk factors associated with cancer deaths. We found that air pollution caused 211,369 TBL cancer deaths; drug use caused 20,540 liver cancer deaths; high body mass index was primarily associated with colon and rectum cancer (33.05%), liver cancer (21.69%), and breast cancer (9.73%) mortality; and high fasting plasma glucose was linked to pancreatic cancer (36.57%), colon and rectum cancer (25.69%), and TBL cancer (24.26%) deaths. Besides, tobacco and occupational risks were identified as the main causes of TBL cancer deaths, while dietary risks and low physical activity were identified the leading causes of colon and rectum cancer deaths [Supplementary Figure 6, http://links.lww.com/CM9/C659]. The analysis conducted at Levels 1 and 2 revealed that significant mortality burden associated with TBL cancers was predominantly attributable to tobacco use and occupational exposures, and colon and rectal cancers were mainly linked to unhealthy dietary patterns and physical inactivity. We further conducted a detailed analysis of Level 3 and Level 4 risk factors, focusing on TBL cancers, as well as colon and rectal cancers, to identify the most

Table 2: Specific risk factors caused cancers death and DALYs in China in 2021.

Risk factors	Deaths, estimated number (95% UI)	DALYs, estimated number (95% UI)
Metabolic risks	128,564 (31,065–232,072)	3,272,144 (847,921–5,892,833)
High fasting plasma glucose	71,789 (7748–139,031)	1,664,284 (179,610–3,236,641)
High body mass index	58,745 (24,601–99,889)	1,658,721 (693,186–2,831,308)
Behavioral risks	1,168,395 (924,751–1,497,233)	28,424,354 (22,369,120–36,677,725)
Alcohol use	102,771 (78,881–135,448)	2,820,895 (2,164,939–3,740,205)
Dietary risks	176,530 (60,802–367,462)	4,407,254 (1,479,112–9,106,093)
Drug use	20,540 (13,489–28,203)	514,499 (346,534–700,626)
Low physical activity	18,624 (10,849–27,939)	375,360 (211,389–574,711)
Tobacco	887,857 (681,458–1,129,265)	20,949,086 (15,961,656–26,880,317)
Unsafe sex	49,821 (36,573–64,084)	1,547,201 (1,122,378–2,007,649)
Environmental/occupational risks	291,270 (205,599–389,270)	6,866,392 (4,852,556–9,251,018)
Air pollution	211,369 (132,080–299,939)	4,894,663 (3,064,923–6,924,984)
Ambient particulate matter pollution	178,625 (103,376–257,019)	4,125,753 (2,375,285–5,932,540)
Household air pollution from solid fuels	32,649 (4,538–110,585)	766,682 (107,194–2,581,290)
Occupational risks	79,175 (55,479–109,148)	1,984,830 (1,388,087–2,734,666)
Occupational exposure to arsenic	5252 (1890–8827)	150,009 (54,125–251,477)
Occupational exposure to chromium	1086 (841–1379)	31,033 (23,985–39,546)
Occupational exposure to nickel	5032 (1057–11,781)	143,765 (30,280–335,913)
Occupational exposure to trichloroethylene	25 (6–48)	802 (176–1547)
Occupational exposure to benzene	484 (135–852)	22,460 (6316–39,695)
Occupational exposure to asbestos	29,020 (18,442–42,779)	535,732 (346,751–802,495)
Occupational exposure to cadmium	511 (375–671)	14,619 (10,759–19,273)
Occupational exposure to formaldehyde	537 (391–722)	23,472 (17,274–31,013)
Occupational exposure to polycyclic aromatic hydrocarbons	3680 (2838–4775)	105,120 (80,088–137,627)
Occupational exposure to sulfuric acid	799 (322–1539)	24,072 (9673–46,270)
Occupational exposure to beryllium	183 (140–236)	5240 (3974–6831)
Occupational exposure to diesel engine exhaust	11,656 (8994–14,676)	332,527 (258,376–419,546)
Occupational exposure to silica	23,468 (11,082–37,637)	669,098 (317,447–1,075,480)
Other environmental risks	29,890 (–15,235–82,113)	695,845 (–358,143–1,914,504)

DALY: Disability-adjusted life year; UI: Uncertainty interval.

significant and specific risk factors for targeted prevention. For colon and rectum cancer, within Level 3 dietary risks, a diet low in milk accounted for the largest proportion of deaths, followed by low whole grains, and high red meat; for TBL cancer, Level 3 analysis showed smoking as the primary cause, followed by particulate matter pollution, and occupational carcinogens [Supplementary Figure 7, http://links.lww.com/CM9/C659]. Further Level 4 analysis within occupational carcinogens revealed that asbestos exposure is the leading cause, followed by silica, and diesel engine exhaust [Supplementary Figure 8, http://links.lww.com/CM9/C659].

Projected future cancer burden

ASDR and age-standardized DALYs rates are projected to 2041 for China, the results indicated that in 2041, the ASDR and age-standardized DALYs were 155.33 per 100,000 population and 3890.33 per 100,000 population, respectively. Moreover, the predicated number of deaths and DALYs were 4.86 million and 102.75 million, respectively [Figure 4]. In 2041, in China the predicated cancer death associated with behavioral risks and environmental and occupational risks showed a decreasing trend, whereas a contrasting pattern was observed for metabolic risks [Supplementary Figure 9, http://links.lww.com/CM9/C659].

Discussion

This study conducted a comprehensive analysis of the cancer burden in China, including an in-depth examination of cancer subtypes, associated risk factors, and projections of future disease trends. Although ASDR shows a decreasing or stable trend in most cancer types, ASIR shows a significant or slow increasing trend in most cancers, such as kidney cancer and multiple myeloma. Meanwhile, one-third of all cancer cases death in China were digestive cancers in 2021.

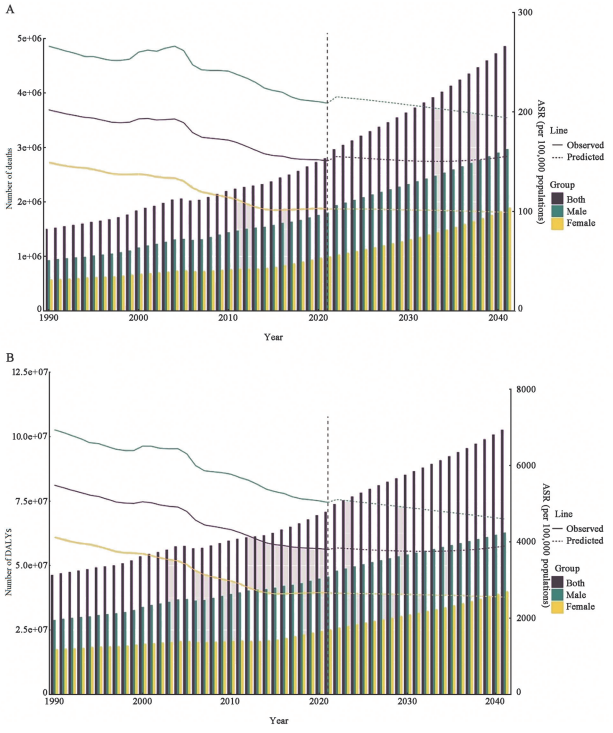


Figure 4: The predicated cancer deaths and DALYs and age-standardized rates in China to 2050 based on GBD 2021. (A) The predicated cancer deaths. (B) The predicated cancer DALYs. ASR: Age standardized rate; DALY: Disability-adjusted life year; GBD: Global Burden of Disease.

The age-specific patterns observed in our study reveal that cancer incidence peaks at younger ages in women compared to men. In 2021, the incidence of cancers peaked in individuals aged 50 to 54 years in women and 65 to 69 years in men. Furthermore, the ASDR and DALYs due to cancer peak in older age groups, particularly among individuals aged 70 to 74 years for both men and women. This highlights the need for improved cancer care and supportive services for the elderly population, who are more likely to experience severe morbidity and mortality from cancer. Among cancer deaths, the top 5 types of cancer in females were TBL cancer, stomach cancer, colon and rectum cancer, breast cancer, and esophageal cancer, the top 5 types of cancer in males were TBL cancer, stomach cancer, esophageal cancer, colon and rectum cancer, and liver cancer. This is different from the latest release of the top 5 deaths from malignant tumors, where liver cancer ranks second in males and esophageal cancer ranks fifth, while in females, colon and rectum cancer and liver cancer rank second and third, respectively.[18] This may be due to the lag in data and the impact of COVID-19 on the collection of data for diagnosis, follow-up, and registration of cancer patients, but both emphasize the burden caused by TBL cancer and digestive cancers.[19–20]

Meanwhile, the sex-related differences in cancer burden also reflect differences in exposure to cancer-inducing risk factors. The incidence rate of cancer in women before the age of 55–59 years in China was higher than that in men. This may be because the high incidence of breast cancer and cervical cancer in women is significantly affected by hormones and reproductive factors, and the onset age is earlier (such as 40–55 years old), while common cancers in men (such as lung cancer and liver cancer) are mostly associated with long-term cumulative risks such as smoking and drinking, and the peak of incidence is usually later than 60 years old. In the past forty years, TBL cancer has long been the leading cause of malignant tumor death in both men and women and the incidence and mortality of lung cancer in males were higher than females. Study also indicates that the age-standardized incidence of lung cancer in the China increased from 16.5 to 37 cases per 100,000 population between 1986 and 2017.[21] In general, smokers have a higher risk of lung cancer than nonsmokers. Efforts are necessary to decrease the incidence of lung cancer by reducing smoking rates.[22,23] Air pollution is another risk factor for lung cancer; thus, it is important to manage air quality now to reduce the risk of lung cancer.[24]

Among the risk factors contributed to digestive cancers in 2021 China, high body mass index, dietary risks, alcohol use, tobacco, and high fasting plasma glucose play an important role. The burden of gastrointestinal

cancers in China can be attributed to population expansion, demographic aging, and the adoption of Western lifestyle practices.[25] Study found that sodium intake, smoking, low fruit intake, and low vegetable intake have slightly improved but are still far from optimal levels.[26] Conversely, high body mass index, consumption of red and processed meat, and low levels of physical activity are predicted to have a greater impact on gastrointestinal cancer in the future.[26] This study also appealed that by adhering to the optimal lifestyle, half of all gastrointestinal cancer events could be prevented by the year 2031 if everyone followed it.

Aging population, lifestyle factors, and screening programs contribute to the rising incidence of bowel and rectal cancer. Implementing and promoting effective screening programs, such as colonoscopy, to detect bowel and rectal cancer early, as well as encouraging a healthy diet, regular exercise, and avoiding smoking and excessive alcohol consumption, can help reduce the burden of these cancers. China has also achieved significant progress in cancer prevention. For example, thanks to vaccination and antiviral therapy for hepatitis B, the rate of liver cancer in China has been experiencing a major decrease.[27] However, the human papillomavirus vaccine has not yet been included in the national immunization plan, which poses a huge burden on cervical cancer.

Some limitations of our study must be acknowledged. First, there are limited data sources in varies provinces. Second, it is difficult to include any association between the COVID-19 pandemic and cancer incidence rate and mortality, which may lead to inaccurate data. Finally, in cases where data were unavailable, GBD estimates were based on covariates and modeling parameters, potentially leading to an overestimation or underestimation of the actual cancer burden. China is a vast country with a large and diverse population, characterized by complex socioeconomic conditions, health risk factors, distribution of medical resources, and regional health disparities.[28] While GBD uses models to fill in data gaps, this model-based estimation may not adequately account for regional differences in China. Therefore, interpretations should be made cautiously.

In conclusion, the disease burden of cancers remains a major public health concern in China. The ASIR increased from 1990 to 2021 and the ASDR decreased from 1980 to 2021 in cancers. TBL cancer remain the most common types of cancer in China.

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Conflicts of interest

None.

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