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ORIGINAL ARTICLE

Cancer incidence, mortality, and burden in China: a time-trend analysis and comparison with the United States and United Kingdom based on the global epidemiological data released in 2020

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Abstract

Background: Cancer is one of the leading causes of death and a main economic burden in China. Investigating the differences in cancer patterns and control strategies between China and developed countries could provide reference for policy planning and contribute to improving cancer control measures. In this study, we reviewed the rates and trends of cancer incidence and mortality and disability-adjusted life year (DALY) burden in China, and compared them with those in the United States (US) and the United Kingdom (UK).

Methods: Cancer incidence, mortality, and DALY data for China, US and UK were obtained from the GLOBOCAN 2020 online database, Global Burden of Disease (GBD) 2019 study, and Cancer Incidence in Five Continents plus database (CI5 plus). Trends of cancer incidence and mortality in China, US, and UK were analyzed using Joinpoint regression models to calculate annual percent changes (APCs) and identify the best-fitting joinpoints.

Results: An estimated 4,568,754 newly diagnosed cancer cases and 3,002,899 cancer deaths occurred in China in 2020. Additionally, cancers resulted in 67,340,309 DALYs in China. Compared to the US and UK, China had lower cancer incidence but higher cancer mortality and DALY rates. Furthermore, the cancer spectrum of China was changing, with a rapid increase incidence and burden of lung, breast, colorectal, and prostate cancer in addition to a high incidence and heavy burden of liver, stomach, esophageal, and cervical cancer.

Abbreviations: DALY, disability-adjusted life year; US, United States; UK, United Kingdom; GBD, Global Burden of Disease; WHO, World Health Organization; CI5 plus, Cancer Incidence in Five Continents plus database; IARC, International Agency for Research on Cancer; ASIR, age-standardized rates of cancer incidence; ASMR, age-standardized rates of cancer mortality; IHME, Institute for Health Metrics and Evaluation; APC, annual percent change; UI, uncertainty interval; *H. pylori*, *Helicobacter pylori*; HBV, hepatitis B virus; HPV, human papillomavirus; EBV, Epstein-Barr virus

Conclusions: The cancer spectrum of China is changing from a developing country to a developed country. Population aging and increase of unhealthy lifestyles would continue to increase the cancer burden of China. Therefore, the Chinese authorities should adjust the national cancer control program with reference to the practices of cancer control which have been well-established in the developed countries, and taking consideration of the diversity of cancer types by of different regions in China at the same time.

KEYWORDS
cancer pattern, incidence, mortality, disability-adjusted life year, trend, risk factor, GLOBOCAN 2020, China, United States, United Kingdom

1 | INTRODUCTION

Cancer is the 2nd leading cause of death in the world, placing a major economic burden on public health systems [1, 2]. The incidence, mortality, and disability-adjusted life year (DALY) burden of cancer vary greatly by country and region, especially between developing countries and developed countries [3]. Many variables, including ecological, environmental, demographic, cultural, and genetic variables, contribute to the heterogeneity of cancer incidence, mortality, and DALY burden [4]. In developed countries, the cancer spectrum is updated in real-time to help optimize the establishment of cancer control systems. However, little information about cancer is available in the majority of developing countries.

China, the biggest developing country in the world, has an immense cancer burden. The cancer spectrum of China is different from that of developed countries, such as the United States (US) and the United Kingdom (UK). Due to rapid economic and social development, the transition from a cancer spectrum of developing countries to the one featured by developed countries has become a major cancer pattern in China [5]. Over the past 35 years, the incidence and mortality rates of liver cancer [6], stomach cancer [7], esophageal cancer [8], and cervical cancer [9] have stayed high, while that of lung cancer [10], breast cancer [11], colorectal cancer [12], and prostate cancer [13] has been growing very fast in China [14]. In order to suit the current socio-economic status of China, an effective cancer control system must be established and refined. Cancer prevention and control strategies implemented in the US and the UK are valuable references for China. Therefore, the comparison of cancer incidence, mortality, and DALYs between China and these developed countries can provide useful information for cancer prevention and control.

In this study, we reviewed the rates and trends of cancer incidence and mortality, DALY burden, and control strategies in China and compared them with those in the US and the UK. All analyses were conducted based on the GLOBOCAN 2020 online database [15], Global Burden of Disease (GBD) 2019 study [16], and Cancer Incidence in Five Continents plus database (CI5 plus) [17]. By investigating the differences of cancer patterns and cancer control strategies between these countries, we hope that our findings could provide reference for policy planning and contribute to improving cancer control measures in China.

2 | MATERIALS AND METHODS

2.1 | Data sources

The data concerning the incidence and mortality of cancer used in the present study were obtained from the GLOBOCAN 2020 online database [15]. GLOBOCAN is a project initiated by the International Agency for Research on Cancer (IARC). It provides national estimates, including incidence, mortality, and prevalence, by cancer site and sex in 185 countries/territories for 36 cancer types [3]. All age-standardized incidence and mortality rates (ASIR and ASMR) of cancer from the GLOBOCAN 2020 were calculated using the world standard population as a reference [18].

The ASIRs of cancer for trend analysis were retrieved from the CI5 plus database series [17]. These data were derived from high-quality national population-based registries from 1998 to 2012. The datasets used in trend analysis of ASIR were "China (5 registries)", "USA, SEER (9 registries)", and "UK, England". "China (5 registries)" includes the data from Shanghai, Jiashan, Zhongshan, Harbin, and Hongkong. "USA, SEER (9 registries)" includes the data from Kentucky, Greater California, Utah, Louisiana, Georgia, New York, Massachusetts, Wisconsin, and Idaho. "UK, England" only includes the data from England, where the majority of the UK population is gathered. All ASIRs from CI5 plus were calculated using the world standard population [19]. For the trend analysis of ASMR in the US and the UK, we referred to the cancer mortality for the period 1998-2012 in World Health Organization (WHO) cancer mortality database [20]. All ASMRs from the WHO cancer mortality database were calculated using the world standard population.

DALYs attributable to cancers for China, US, and UK in 1990 and 2019 were obtained from the GBD 2019 online results tool [16], which was engineered by the Institute for Health Metrics and Evaluation (IHME). GBD project estimates mortality, years of life lost, years of life lived with disability, and DALYs by age and sex for 87 risk factors and risk factor combinations for 204 countries and territories annually [21]. In the present study, DALYs per 100,000 population in 2019 estimates for 28 cancer sites in China, US, and UK were presented by sex and age. The percentage and ranking changes in all-age and age-standardized DALY rates from 1990 to 2019 were shown to reflect the trends of cancer burden in China, US, and UK. All age-standardized DALY rates were calculated using the GBD reference population [21].

2.2 | Statistical analysis

Joinpoint regression models [22] were used to examine the time trends in ASIRs for selected cancer sites in China, US, and UK for the period 1998-2012. The Joinpoint software (version 4.8.0.1; National Cancer Institute, Rockville, MD, US) was used to appreciate time trends in a structured manner and test which trends between joinpoints are statistically significant. A maximum number of three line segments (two join-points) were applied in the models. To indicate the direction and magnitude of the trends, the annual percent change (APC) was calculated in this study. The term "decrease" or "increase" was used when the slope (APC) of the trends was significantly different from zero. *P* value less than 0.05 was considered statistically significant.

3 | RESULTS

3.1 | Cancer incidence and mortality in China, US and UK

Based on the estimates from the GLOBOCAN 2020, 19,292,789 new cancer cases (including non-melanoma skin cancer) were diagnosed in the world in 2020. Nearly 23.7% (4,568,754) of these cases occurred in China, which included 2,475,945 males and 2,092,809 females. The ASIR for all cancers was 204.80 per 100,000 population (Supplementary Table S1). Men showed higher ASIR than women (225.40 per 100,000 population for men *vs*. 188.20 per 100,000 population for women). In both sexes combined, breast cancer showed the highest ASIR (39.10 per 100,000 population; this data only contains breast cancer for females), closely followed by lung cancer (34.80 per 100,000 population), colorectal cancer (23.90 per 100,000 population), stomach cancer (20.60 per 100,000 population), liver cancer (18.20 per 100,000 population), and esophageal cancer (13.80 per 100,000 population; Figure 1A and Supplementary Table S1). Of note, 38.8% of all cancer cases diagnosed in China were digestive cancers (including colorectal cancer, stomach cancer, liver cancer, and esophageal cancer) in 2020.

As shown in Supplementary Table S2, about 3,002,899 people in China died from cancer (including non-melanoma skin cancer) during 2020, accounting for 30.2% (3,002,899/9,958,133) of all cancer deaths worldwide. The ASMR for all cancers was 129.40 per 100,000 population in China. Men had nearly a 40.1% higher ASMR than women (163.90 per 100,000 population for men *vs*. 98.10 per 100,000 population for women). Lung cancer was the leading cause of cancer death with an ASMR of 30.20 per 100,000 population, followed by liver cancer (17.20 per 100,000 population), stomach cancer (15.90 per 100,000 population), esophageal cancer (12.70 per 100,000 population), colorectal cancer (12.00 per 100,000 population), and breast cancer (10.00 per 100,000 population; Figure 1A and Supplementary Table S2). Compared with the cancers from other systems, the ASMR of digestive cancers was much higher.

There was a huge variation in cancer incidence and mortality among China, US and UK in 2020. The ASIR of all cancers in China (204.80 per 100,000 population) was comparable to that in the world (201.00 per 100,000 population) but lower than those in the US (362.20 per 100,000 population) and UK (319.90 per 100,000 population; Supplementary Table S1). However, China had a much higher ASMR than the US and UK (129.40 per 100,000 population for China *vs*. 86.30 per 100,000 population for the US and 100.50 per 100,000 population for the UK; Supplementary Table S2). Additionally, the proportion of lung, breast, colorectal, and prostate cancer combined in China (41.7% of all new cancer cases) was similar to that in the US (37.1%) and UK (47.0%; Supplementary Table S1). Unlike the US and the UK, where prostate cancer was the mainstay, China was dominated by lung cancer(Supplementary Table S1). Liver, stomach, esophageal, and cervical cancer were more commonly seen in China (29.0% of all new cancer cases) than in the US (4.5%) and UK (6.2%; Supplementary Table S1). They were responsible for 37.4% of all cancer deaths in China, which was only less than 12% of all cancer deaths in either the US or UK (Supplementary Table S2).

The top 10 cancer types by the ASIR and ASMR for males and females in the three countries in 2020 are summarized

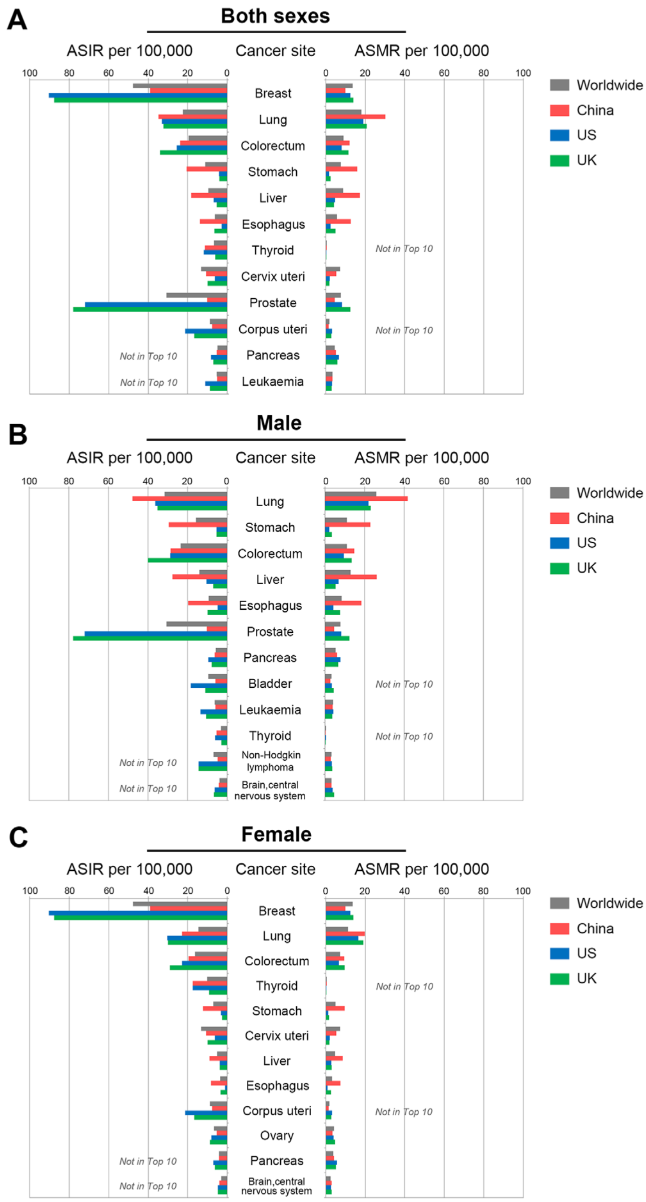

FIGURE 1 ASIR and ASMR per 100,000 population of selected types of cancers in China, US, UK, and worldwide in 2020. ASIR and ASMR data of cancers in both sexes (A), male (B), and female (C). The data used to generate this figure were from the GLOBOCAN 2020 database. ASIR data from China were used to rank the order of cancer sites. Abbreviations: ASIR, age-standardized rates of cancer incidence; ASMR, age-standardized rates of cancer mortality; US, United States; UK, United Kingdom.

in Figure 1B and C. Lung cancer and colorectal cancer were the top 5 cancers diagnosed with the greatest frequency in each of the three countries for males. Chinese men had a much higher incidence of stomach cancer, liver cancer, and esophageal cancer than those from the US and UK. However, in the US and UK, the ASIRs of prostate cancer and skin melanoma in males were higher than those in China. For females, breast cancer, lung cancer, and colorectal cancer were the top 5 common cancers for females in each of the three countries. Chinese women were more likely to have stomach cancer and cervical cancer, while women from the US and UK were more likely to have tumors arising from corpus uteri and skin melanoma. It is worth noting that both males and females had higher ASMRs for stomach cancer and liver cancer in China than those in the US and UK.

3.2 | Time trends of cancer incidence and mortality in China, US and UK

Time trend analysis for cancer incidence data obtained from the CI5 plus between 1998 and 2012 showed that the ASIR of all cancers in Chinese men declined from 236.10 per 100,000 population in 2001 to 215.06 per 100,000 population in 2012, although it increased slightly in the early period (1998-2001; Figure 2A). However, the ASIR of all cancers in Chinese women exhibited a rising trend until 2000, followed by a stabilization up to 2009 and a significant increase during the period from 2009 to 2012 (Figure 2A). The changes of ASIR in females from UK were similar to those from China, while a decreased trend was observed for both sexes from the US (Figure 2A). It is worth noting that the ASMR of both sexes in the US and UK dropped significantly overall study period (Figure 2B).

During the same time period, an obvious heterogeneity in time trends for cancer incidence was observed in China, US, and UK (Figure 3). For lung cancer, the ASIRs of females were lower than those of males in the three countries. Males from the US, which had higher ASIR of lung cancer than those in China in 1998, showed a rapid decline throughout the whole study period and reached a level much lower than those in China eventually. In females, although the US had the highest lung cancer ASIR, a steady downward trend was observed, reaching an ASIR of 28.67 per 100,000 population in 2012. However, females from China and UK showed large increase in lung cancer ASIR during the period 2010-2012 and 2003-2012, respectively. Similarly, people from the US had the highest ASIR of breast cancer and prostate cancer, which decreased sharply throughout the study period, but the ASIR of breast cancer and prostate cancer, which were significantly low in China, increased clearly in the same period. For colon cancer, the ASIR of both sexes in US has declined rapidly since 1998 and that in China remained relatively stable during 1998-2012. However, the ASIR of colon cancer in the UK slowly decreased between 1998 and 2003, and increased between 2003 and 2012, whether in men or in women. It should be noted that the ASIR of digestive cancers other than colorectal cancer (liver cancer, stomach cancer, and esophageal cancer) in China has been

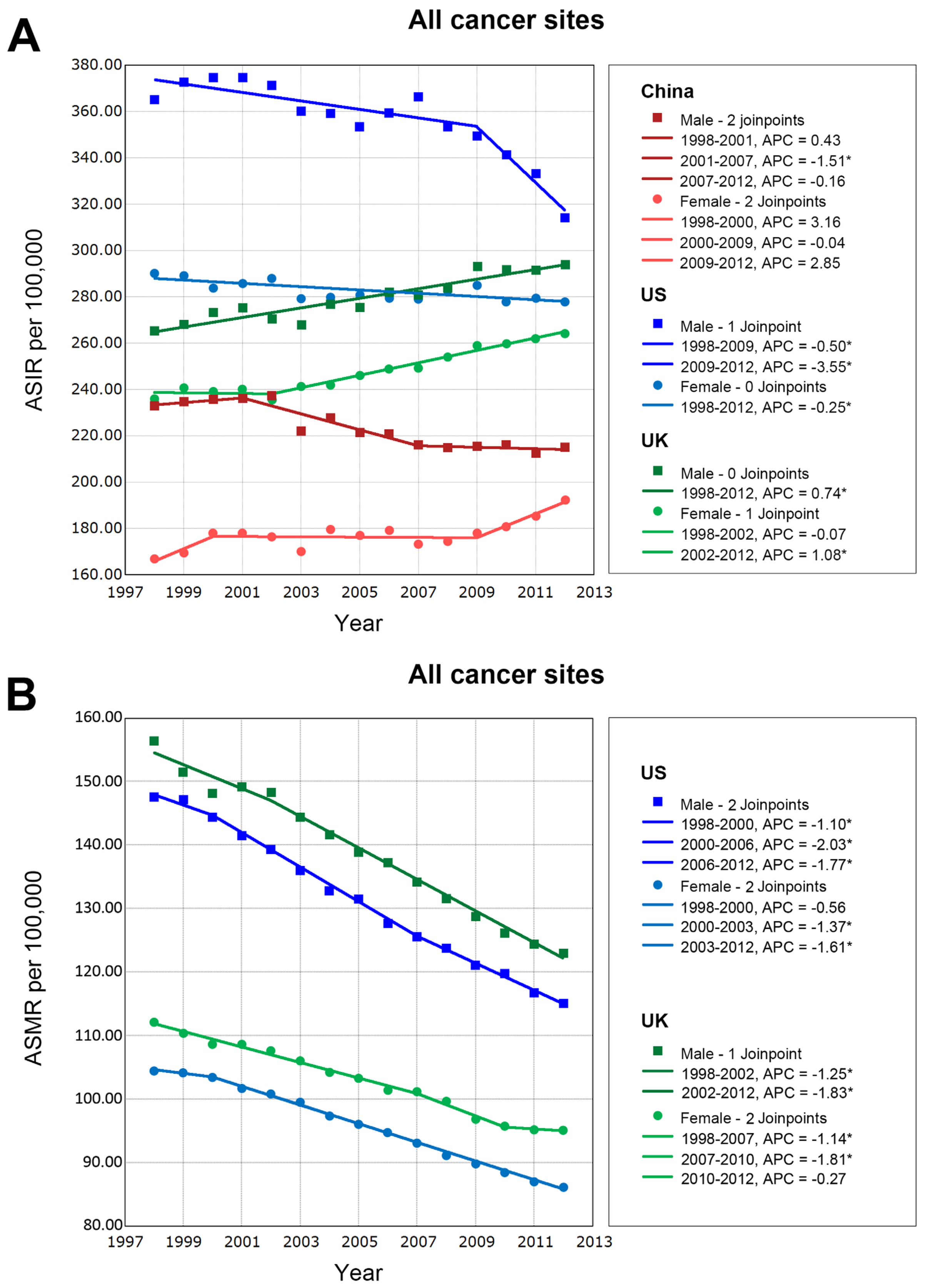

FIGURE 2 **Trends in ASIR (A) and ASMR (B) of all cancer sites by gender in China, US, and UK**. The ASIR data used to generate this figure were from the CI5 plus database. The ASMR data used to generate this figure were from the WHO cancer mortality database. Abbreviations: ASIR, age-standardized rates of cancer incidence; ASMR, age-standardized rates of cancer mortality; US, United States; UK, United Kingdom; WHO, World Health Organization.

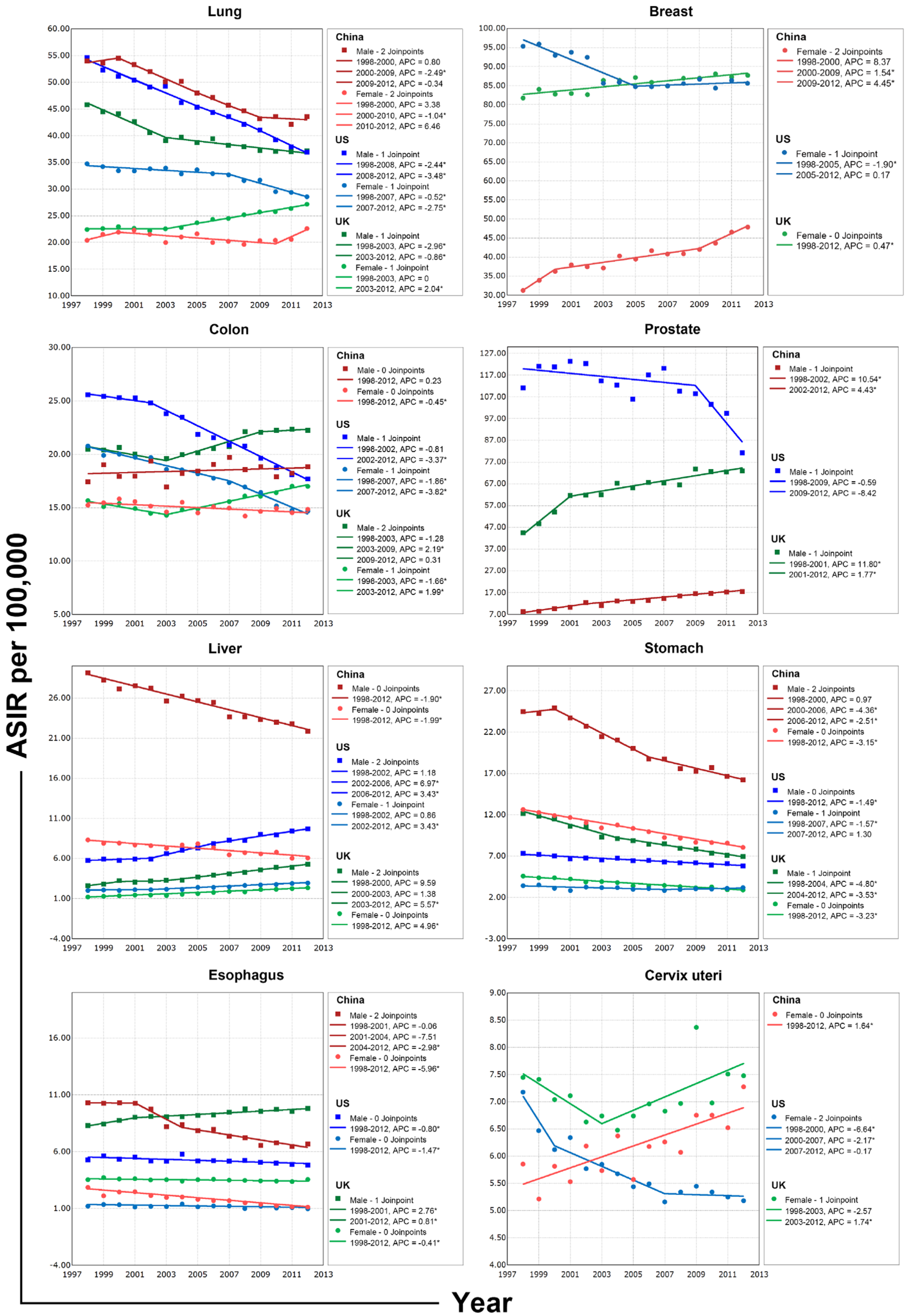

FIGURE 3 **Trends in ASIR by cancer site and gender in China, US, and UK**. The data used to generate this figure were from the CI5 plus database. Abbreviations: ASIR, age-standardized rates of cancer incidence; US, United States; UK, United Kingdom; APC, annual percent change.

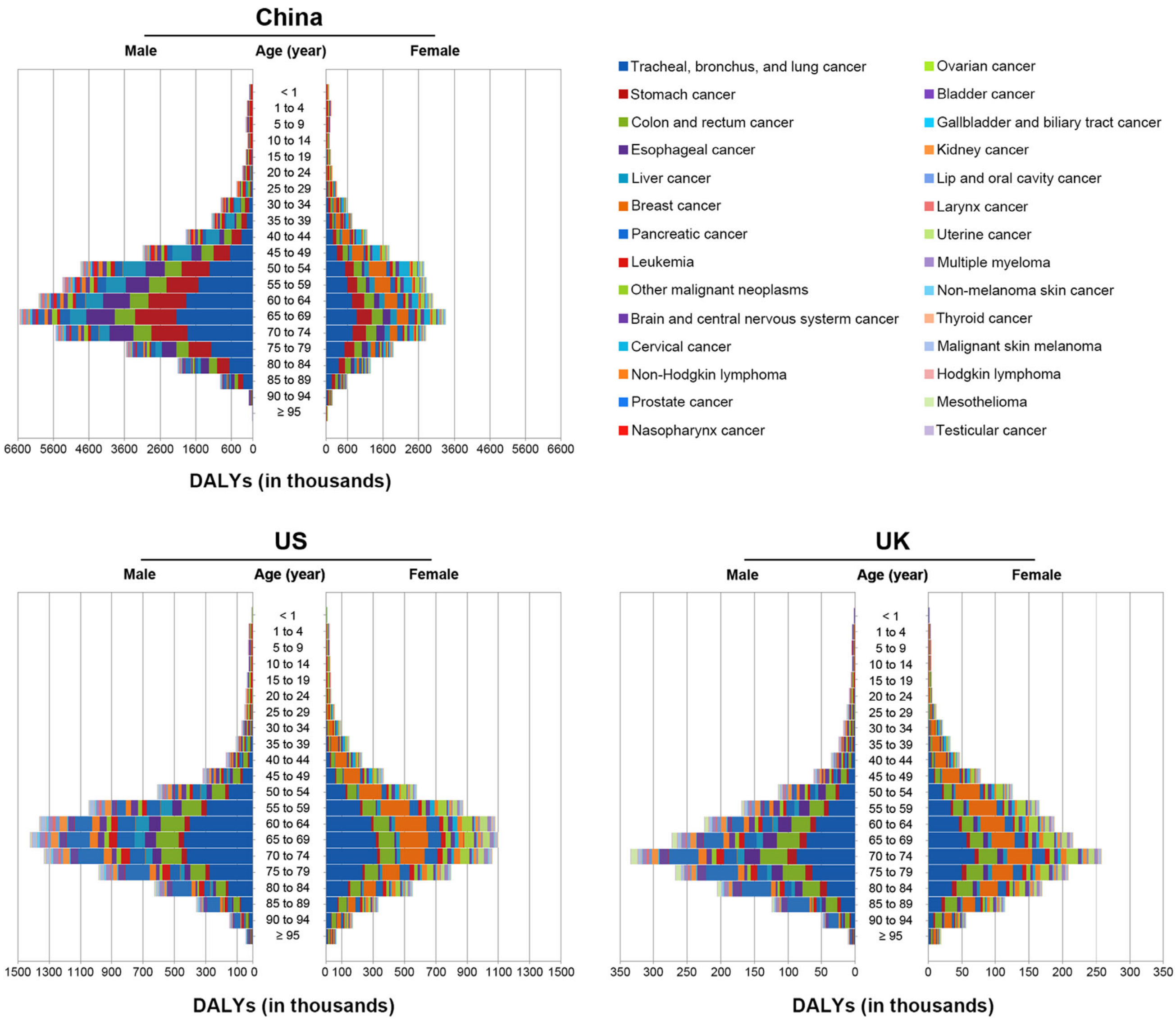

FIGURE 4 **Numbers of DALYs attributable to cancers by age and gender in China, US, and UK in 2019**. The estimates used to generate this figure were from the GBD study. Abbreviations: DALY, disability-adjusted life year; GBD, Global Burden of Disease; US, United States; UK, United Kingdom.

declining throughout the study period, especially among men, but those in the US and UK remained stable or increased slightly. On the contrary, in China, the ASIR of cervical cancer increased from 5.86 per 100,000 population in 1998 to 7.28 per 100,000 population in 2012, while a sharp decrease of cervical cancer ASIR (from 7.18 to 5.18 per 100,000 population) was observed in the US during the same period.

3.3 | Cancer burden in China and comparison with the US and UK

The GBD 2019 estimated that cancers resulted in 67,340,309 DALYs in China (Supplementary Table S3). Lung cancer represented the highest DALY burden for China (17,128,584 DALYs; 25.4% of all cancer DALYs), followed by stomach cancer (9,824,993 DALYs; 14.6%), colorectal cancer (6,394,918 DALYs; 9.5%), esophageal cancer (5,759,997 DALYs; 8.6%), and liver cancer (5,325,461 DALYs; 7.9%; Supplementary Table S3). These 5 cancer types accounted for more than 65% of cancer DALYs in China. As shown in Figure 4, leukemia and brain and nervous system cancer were the main causes of cancer burden for children and adolescents (<20 years). Among the young (20-44 years) and middle-aged men (45-59 years), lung cancer, stomach cancer, and liver cancer emerged as predominant causes of the cancer burden, and the first two types of cancer continued to be the main contributors to the cancer burden of older men

(≥60 years). The three leading causes of cancer burden in young and middle-aged women were lung cancer, breast cancer, and cervical cancer; however, those in older women were lung cancer, stomach cancer, and colorectal cancer.

The cancer burden and its causes differed between China, US, and UK in 2019. China had higher age-standardized DALY per 100,000 population for all cancers combined than the US and UK. The age-standardized DALY rate in China was 3411.12 per 100,000 population, and 3196.73 and 3273.08 per 100,000 population for the US and UK, respectively (Supplementary Table S3). The populations with the highest cancer burden in China were younger than those in the UK (Figure 4). The largest contributor to the cancer burden for the three countries was lung cancer (Supplementary Table S3). In addition to lung cancer, the top 5 cancer burden contributors in China also included digestive cancers (stomach cancer, colorectal cancer, esophageal cancer, and liver cancer), while those in the US and UK were colorectal cancer, breast cancer, prostate cancer, and pancreatic cancer (Supplementary Table S3). In terms of the DALY composition by age, leukemia was the largest cancer burden contributor for children and adolescents in the three countries, followed by brain and nervous system cancer (Figure 4). For young and middle-aged men, the leading causes of DALY were lung cancer and stomach cancer in China, but lung cancer and colorectal cancer in the US and UK (Figure 4). The predominant cause of the cancer burden among young and middle-aged women was breast cancer in the US and UK, but lung cancer in Chinese women (Figure 4). Among elder people in the three countries, the top contributor to DALY burden was lung cancer (Figure 4).

3.4 | Changes of cancer burden in China and comparison with the US and UK

Between 1990 and 2019, the age-standardized DALY rate in China decreased by 27.3%, from 4690.07 (95% uncertainty interval [UI] = 5238.08-4141.07) per 100,000 population in 1990 to 3411.12 (95% UI = 3934.24-2923.22) per 100,000 population in 2019. The rate decreased by 22.4% in males and 33.7% in females. The ranking changes in all-age DALY rates attributable to 28 cancer types in China are summarized in Figure 5. Lung cancer became the leading cause of DALY burden in 2019, replacing stomach cancer in 1990. Colorectal cancer, breast cancer, and prostate cancer all increased in the ranking to become the third, sixth, and thirteenth leading cancers of DALY burden. The reverse occurred at stomach cancer and liver cancer. Their all-age DALY rates have decreased by 0.9% and 41.5% over the last 29 years, leading to a decrease in their ranking from

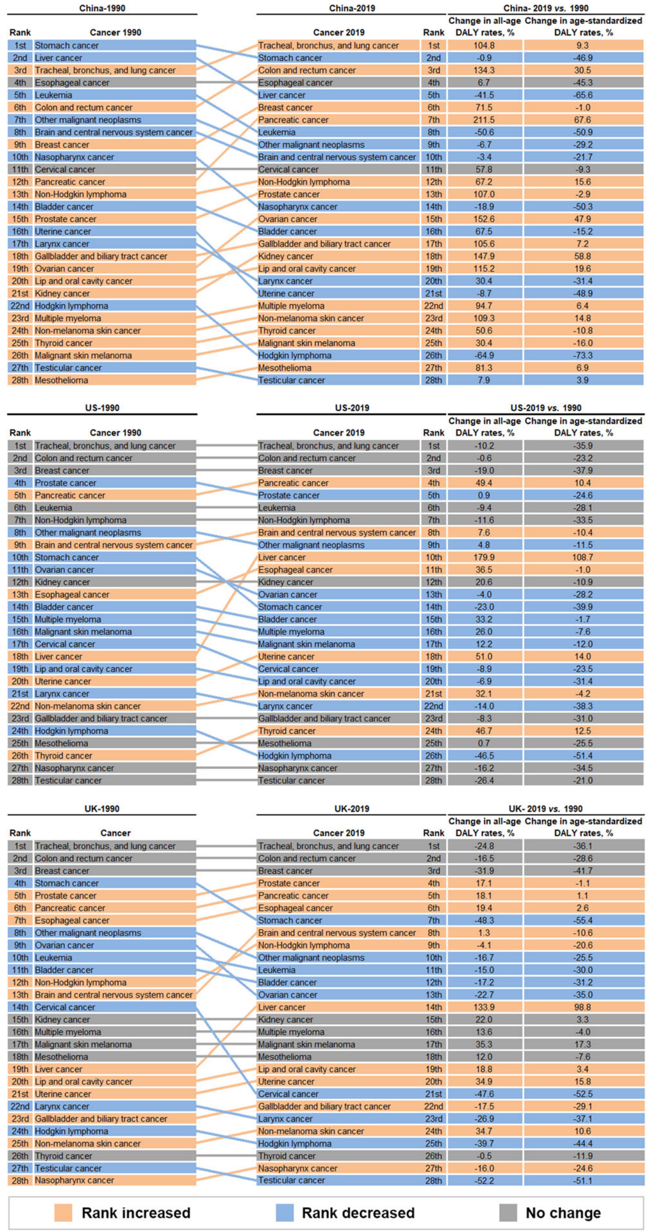

FIGURE 5 Rank changes in DALYs attributable to cancers and percentage change in all age and age-standardized DALY rates in China, US, and UK from 1990 to 2019. The estimates used to generate this figure were from the GBD study. Age-standardized rates were calculated using the GBD reference population. Abbreviations: DALY, disability-adjusted life year; GBD, Global Burden of Disease; US, United States; UK, United Kingdom.

the first to the second and the second to the fifth, respectively. The rankings of esophageal cancer and cervical cancer remain unchanged, even though the age-standardized DALY rates decreased by 45.3% and 9.3% during 1990-2019, respectively.

The changes of cancer burden in the US and UK were quite different to those in China (Figure 5). Although lung cancer, colorectal cancer, and breast cancer were still the top 3 leading cancer for DALY burden in the US and UK over the last 29 years, their all-age and age-standardized DALY rates declined significantly over this period. The biggest change of cancer burden in the US and UK was observed for liver cancer. All-age DALY rates of liver cancer have increased by 179.9% in the US and 133.9% in the UK since 1990, leading to an increase in its ranking from the eighteenth to the tenth in US and the nineteenth to the fourteenth in UK. Additionally, the age-standardized DALY rate of cervical cancer declined significantly, especially in UK, declined by 52.5% during 1990-2019, leading it from fourteenth in 1990 to fall outside the top 20 causes in 2019.

4 | DISCUSSION

In this study, we conducted a comprehensive epidemiological analysis of cancer incidence, mortality, and DALYs in China based on the most recent results from the GLOBOCAN 2020, GBD 2019, and CI5 plus program. Additionally, we also focus on the time trends of cancer incidence, mortality, and DALY burden in the past three decades and compared the differences between China, US, and UK using high-quality data from CI5 plus and GBD database. We found that China has lower cancer incidence but higher cancer mortality and DALY rates than the US and UK. Most of the cancer-related deaths and DALYs in China were from the digestive cancers (colorectal cancer, stomach cancer, liver cancer, and esophageal cancer). Furthermore, the cancer spectrum of China is changing from a developing country to a developed country, with a rapid increase incidence and burden of lung, breast, colorectal, and prostate cancer in addition to a high incidence and heavy burden of liver, stomach, esophageal, and cervical cancer.

According to the estimates by the GLOBOCAN 2020, 23.7% of newly diagnosed cancer cases in the world have occurred in China. However, cancer deaths in China accounted for 30.2% of all cancer deaths. In addition, the ASIR for all cancers was relatively lower but the ASMR and DALY burden was significantly higher in China as compared to those in the US and UK. These seemingly contradictory situations can be explained by the following reasons. First, different cancer patterns by countries could lead to the higher mortality rate in China. Apart from breast, lung, and colorectal cancer, the most common cancers in China were stomach, liver, and esophageal cancer, all of which had poor prognosis and heavy DALY burden [23]. In contrast, the most common cancers in US and UK were cancers with a low mortality rate, such as prostate cancer, tumors arising from corpus uteri, and skin melanoma [23]. Secondly, lack of early screening awareness results in a low early cancer detection rate, and thereby affects the prognosis and DALY burden of cancer patients in China. Although the cancer incidence in US and UK was higher than that in China, most cancer cases in these two countries were detected through early screening [24, 25]. Therefore, early cancer patients with a better prognosis accounted for a larger proportion of all cancer patients in US and UK. Third, the health care availability and accessibility in China are unequally distributed across the country [26]. Lastly, the application of new anticancer drugs and therapeutic strategies in China is lagging behind.

The trend analysis of cancer ASIR and ASMR based on the data retrieved from CI5 plus database indicated that the ASIR and ASMR of all cancer-types in US maintained a continuous downward trend between 1998 and 2012. Despite the ASIR of all cancer types in UK increased slightly, the ASMR has declined significantly during the same time period. In China, the overall ASIR of men remained stable, while that of women increased gradually. However, according to the 2015 Chinese Cancer Statistics, the overall ASMR in China has steadily increased between 2000 and 2011 [27]. These findings reflect the huge differences in cancer prevention and management between China and the US or UK. Therefore, learning the experience of effective practices of cancer prevention and management in US and UK has become particularly important.

The implementation of population-based cancer screening programs is one of the most effective measures adopted by the US and UK. It significantly reduced the mortality and DALY burden of some cancer types. For example, the UK began to implement national population-based cancer screening for breast and cervical cancer in 1980s. This measure partly led to a reduction in the ASMR of breast cancer from 28.92 per 100,000 population to 15.90 per 100,000 population cases between 1990 and 2013, while the ASMR of cervical cancer decreased from 4.78 per 100,000 population to 1.64 per 100,000 population during the same period [28]. Similarly, since the implementation of colorectal cancer screening in the UK in 2006, the ASMR for colorectal cancer in males has dropped from 14.36 per 100,000 population to 12.67 per 100,000 population within 7 years, while that in females has dropped from 8.97 per 100,000 population to 8.26 per 100,000 population [29]. The effectiveness of cancer screening mainly depends on the population coverage and adherence for the target population. In the US, where the ASMR for breast cancer, cervical cancer, and colorectal cancer has fallen significantly, the adherence rates of the related cancer screening programs were as high as about 72%, 81%, and 63%, respectively [30]. So far, with the exception of breast and cervical cancer screening, China has not conducted a screening for other cancer types in the national population. However, the Chinese government has implemented cancer screening based on populations in high-risk areas since 2006 for breast, colorectal, lung, stomach, esophageal, and nasopharyngeal cancer. Moreover, the increasing awareness of early cancer screening in urban areas of China may partly explain the decline in the mortality of stomach and esophageal cancer. The challenge that limits the implementation of cancer screening in China is that the coverage rate for the entire country is still insufficient and needs further improvement.

Smoking is a high-risk factor for cancer worldwide, attributed to the occurrence of about 20 malignancies and more than 70% of lung cancer cases in the world were caused by smoking [31, 32]. Therefore, implementing strict tobacco control policies is an effective measure to reduce the ASIR and ASMR of cancer. In order to reduce the global cigarette consumption rate, the World Health Organization issued the "Framework Convention on Tobacco Control" in 2003. A total of 168 countries signed the agreement and further drafted their own tobacco control strategies. The US is a pioneer in anti-tobacco campaigns. It took the lead in implementing strict tobacco control measures as early as the 1960s. Since then, the number of smokers in the US has continued to decline (from 42% in 1965 to 14% in 2017) [33]. The mortality rate of lung cancer in males from the US decreased by 43% during 1990-2014 [34]. The UK is the country with the greatest efforts to control tobacco. Its smoking rate has dropped from 50% in the 1970s to 15% in 2016 [35]. The incidence and mortality of lung cancer in the UK has been in constant decline between 1995 and 2013, dropping by more than 25% and 35%, respectively [33]. Although the Framework Convention on Tobacco Control was ratified in 2005 and the National Assembly of a law on tobacco control was adopted in 2006, the tobacco control situation in China is still unsatisfactory. The 2015 China Tobacco Control Report indicated that the smoking rate of Chinese men was found to be greater than 50% [36]. As such, the incidence of lung cancer in Chinese men has been higher than that of the US and UK. The smoking rate of Chinese women was relatively low when compared with that of the US and UK (3.0% for China [36] *vs.* 15.3% for the US [37] and 20.0% in the UK [38]), but the incidence of lung cancer in Chinese women rose rapidly and will soon exceed that of the US and UK. One possible explanation is that Chinese women are at greater risk of being exposed to second-hand smoke.

The prevention of chronic infection is recognized as the most effective strategy for the prevention of infection-related cancers, such as stomach, liver, cervical, and nasopharyngeal cancer. Infection with *Helicobacter pylori* (*H. pylori*) is the strongest risk factor for stomach cancer. The prevalence of *H. pylori* in China was ~20% higher than that in the US and UK [39]. This is probably one of the main reasons why the incidence of stomach cancer in China was higher than that in the US and UK. Moreover, the incidence of stomach cancer in Chinese men has declined by 4.36% per year from 2000 to 2006, and 2.51% from 2006 to 2012. A similar decline in incidence has also been observed in Chinese females (3.15% from 1998 to 2012) [27]. The reasons for the declines are thought to be partly caused by the decrease in *H. pylori* prevalence [40] as a result of greater awareness for treating *H. pylori* infection. Another infection-related cancer with a declining incidence in China is liver cancer. The infant routine immunization against hepatitis B virus (HBV) in China since 1992 might be one of the main reasons for the decline in the incidence of liver cancer [41]. Human papillomavirus (HPV) has been implicated in 99.7% of cervical cancer cases worldwide [42]. HPV vaccination was first implemented in the US in 2006. Since then, the prevalence rate of vaccinated HPV (HPV16 and HPV18) has dropped from 11.5% before 2006 to 5.1% in 2010 [43], and the incidence of cervical cancer has subsequently dropped [44]. In China, HPV vaccination has been lagged for more than 10 years until the China Food and Drug Administration approved a bivalent HPV vaccine in 2017, but it has not yet been included in the national immunization plan. Nasopharyngeal cancer is rare in most parts of the world but is a common malignancy in southern China [45]. It is consistently associated with Epstein-Barr virus (EBV) infection [46]. Unfortunately, until now there is still no vaccine that can prevent NPC by reducing the EBV infection rate.

In addition to the measures mentioned above, raising awareness about healthy lifestyle by education is also an effective way to prevent cancer. Unhealthy lifestyles, such as increase in obesity, high consumption of red meats, and sedentary behavior, are one of the reasons for the increase in the incidence of lung, breast, colorectal, and prostate cancer [14]. China is undergoing an unhealthy lifestyle transition, so the incidence of lung, breast, colorectal, and prostate cancer is rising. Additionally, malnutrition or nitrosamine-contaminated food intake may be a key factor in the high incidence of upper gastrointestinal cancer in China [14]. From 2001 to 2012, the incidence of esophageal cancer and stomach cancer in China decreased by 2.51%-7.51% every year [27], which is considered to be due to improved hygiene and food quality, better food preservation, and less salty food consumption.

The present study has several limitations. First, only five registries in China were included for the time trend analysis of cancer incidence, covering around 4% of the national population. Therefore the results should be interpreted with caution due to the lack of representativeness. Second, due to the variations in data collection and reporting systems across countries, the comparison of estimates from different countries may be compromised. Moreover, since the data collected after 2012 was not available, trends in the recent years could not be evaluated.

5 | CONCLUSIONS

In summary, the cancer incidence rate in China was slightly lower, but cancer mortality and DALY rates were much higher than those in the US and UK due to the special circumstances and challenges faced by China, such as huge population, uneven development of its various regions, and relative laggard cancer control strategies. The cancer spectrum of China is changing from a developing country to a developed country. In the next decade, population aging and increase of unhealthy lifestyles will continue to increase the cancer burden in China. Therefore, the Chinese government should make every effort to promote cost-effective cancer screening and immunization programs, implement strict tobacco control policies, and commit to awareness-raising of healthy lifestyles through education. Additionally, Chinese government should adjust the national cancer control program taking into consideration the diversity of cancer types across different regions of China at the same time.

DECLARATIONS

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The datasets used in this study are all publicly available.

COMPETING INTERESTS

The authors declare that they have no competing interests.

FUNDING

Not applicable.

AUTHORS' CONTRIBUTIONS

HBQ collected the related data materials, conducted the analysis, and drafted the manuscript. SMC directed the study's analytic strategy and reviewed the manuscript. RHX designed the entire study. All authors read and approved the final manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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