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Lifetime risk of developing and dying from cancer in Henan Province, China: current status, temporal trends, and disparities

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ABSTRACT

Objective: To understand the current status and changing trends in the lifetime risk of residents in Henan Province, China to develop and die from cancer.

Methods: Lifetime risk was estimated using the Adjusted for Multiple Primaries (AMP) method, incorporating cancer incidence, mortality, and all-cause mortality data from 55 cancer registries in Henan Province, China. Estimates were calculated overall and stratified by gender and area. The annual percent change (APC) in lifetime risk from 2010 to 2020, stratified by gender and cancer site, was estimated using a log-linear model.

Results: In 2020, the lifetime risk of developing and dying from cancer was 30.19 % (95 % CI: 29.63 %–30.76 %) and 23.62 % (95 % CI: 23.28 %–23.95 %), respectively. These estimates were higher in men, with values of 31.22 % (95 % CI: 30.59 %–31.85 %) for developing cancer and 26.73 % (95 % CI: 26.29 %–27.16 %) for dying from cancer, compared with women, who had values of 29.02 % (95 % CI: 28.12 %–29.91 %) and 20.08 % (95 % CI: 19.51 %–20.64 %), respectively. There were also geographical differences, with higher estimates in urban areas compared with rural areas. Residents had the highest lifetime risk of developing lung cancer, with a rate of 6.94 %, followed by breast cancer (4.14 %), stomach cancer (3.95 %), esophageal cancer (3.75 %), and liver cancer (2.86 %). Similarly, the highest lifetime risk of dying from cancer was observed for the following sites: lung (5.99 %), stomach (3.60 %), esophagus (3.39 %), liver (2.78 %), and colorectum (1.55 %). Overall, the lifetime risk of developing cancer increased, with an APC of 0.75 % ($P < 0.05$). Varying trends were observed across different cancer sites. There were gradual decreases in nasopharynx, esophagus, stomach, and liver cancers. Conversely, increasing trends were noted for most other sites, with the highest APCs observed in thyroid, prostate, lymphoma, kidney, and gallbladder cancers.

Conclusion: The lifetime risks of developing and dying from cancer were 30.19 % and 23.62 %, respectively. Variations in cancer risk across different regions, genders, specific cancer sites, and over calendar years provide important information for cancer prevention and policy making in the population.

1. Introduction

Cancer represents a globally significant public health challenge, exerting a profound impact on population health and standing as a leading global cause of death.[1] The burden of cancer remains substantial, influenced by the progression of industrialization, an aging population, and the cumulative effects of cancer-related risk factors.[2] In response, the focus on cancer prevention is steadily increasing. The lifetime risk of developing cancer or dying from cancer, defined as the probability of an individual being diagnosed with or dying from cancer over their entire lifetime,[3,4] is a widely used index that indicates the prevalence of cancer in specific populations and informs public health policy. However, data on this aspect is seldomly reported for the Chinese population and has only been addressed in a few articles.[5–7] These studies have reported the overall and major site-specific cancer risks among men and women in China, with the estimated value of 31.01 % and 26.60 %, respectively.[5] However, these data do not fully reflect the cancer risk in the Chinese population. Significant differences in risk factors and cancer burden existed in different parts of China,[8] implying that people in different regions may bear different risks of developing cancer. Assessing cancer risk within different regions of China plays a crucial role in reducing the disparity of cancer burden across the country.[8–10] There-

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fore, there is an urgent need for a systematic description of the Chinese population and its sub-populations in this regard. Henan Province, with a population of 99 million, is one of the most populous provinces in China. According to the Seventh National Population Census conducted in 2020, 55.4 % of its residents live in urban areas, which represents 7.04 % of the national population.[11] With the rapid advancement of industrialization, the risk factors related to cancer are also undergoing changes. Therefore, understanding the lifetime cancer risk among the population of Henan Province is crucial.

The Adjusted for Multiple Primaries method (AMP) is a recommended and practical approach for estimating the lifetime risk of developing cancer using the Population-Based Cancer Registration (PBCR) data, adjusting for the impact of multiple primary cancers.[3] This method is particularly useful when precisely excluding multiple primary cancer cases is challenging or when individual case data are unavailable.

This article quantitatively assessed the lifetime cancer risk in Henan Province, China, considering both overall and stratified risks based on regions, gender, and cancer types, utilizing data from 55 population-based cancer registries. The findings from this analysis provide insights for establishing priority cancer prevention and control strategies.

2. Materials and methods

2.1. Data sources

Data on new cancer cases, deaths, all-cause mortality, and corresponding population figures were sourced from the Henan Provincial Cancer Registry (HPCR), compiled by county-level PBCRs. Primary sources for identifying cancer cases include various medical institutions, community health service centers, and a three-tier physician network covering counties, townships, and villages. Additional sources included insurance system data, the urban and rural residents' basic mdedical insurance system (URRBMI), and the vital statistics system.

The lifetime risk of developing and dying from cancer in 2020 was estimated using data from 55 county-level cancer registries in Henan, China, covering 43 million, which accounts for 37.4 % of the total population in Henan Province. Temporal trends in lifetime risk overall and stratified by gender and cancer sites from 2010 to 2020 were analyzed using data from 16 continuous cancer registries covering 13 million people and representing 12.2 % of the total population.

2.2. Quality control

The HPCR has implemented a quality control process based on the "Guidelines for Cancer Registration in China" and the data quality assessment standards of the International Agency for Research on Cancer and the International Association of Cancer Registries (IARC/IACR).[12,13] Detailed quality control measures have been previously described.[14] In brief, internal consistency of cancer cases were first checked, followed by the quality indices such as completeness and validity by county-level and provincial cancer registries. Case information was sent back to data sources for correction and supplementation when issues were identified during quality control.

2.3. Statistical analysis

The lifetime risk of developing and dying from cancer was calculated using the AMP method, which corrects for the inclusion of multiple primary cancers in the incidence rates.[3,4] Cancer incidence, cancer mortality, and all-cause mortality rates by 5-year age groups were used to estimate the lifetime risk of cancer by sex at different age spans, which represents the probability of being diagnosed with cancer for the whole life time. The formula for calculating lifetime risk is as follow: (Eq. (1)),

$$S = \sum_{i=1}^{f} \frac{R_i}{R_i + M_i - D_i} S_0(a_i) \times \left(1 - exp\left(-\frac{W_i}{N_i}\left(R_i + M_i - D_i\right)\right)\right) \quad (1)$$

where S indicates the probability of being diagnosed with cancer or dying from cancer, $R_i$indicates the annual number of cancer cases when calculating lifetime risk of developing cancer, and indicates the annual number of cancer related deaths when calculating lifetime risk of dying from cancer, $D_i$indicates the annual number of cancer related deaths, $M_i$indicates the total number of deaths due to all causes in the population, $N_i$indicates the population, $S_0(a_i)$ indicates the probability of being alive and cancer free at age a_i, and w_i denotes the number of years included inthe age group i.

Lifetime risk was expressed as percentages, with confidence intervals estimated using the binomial method provided by Zheng[5] and Wang,[6] also expressed as percentages. Lifetime risk, both overall and stratified by area, gender, and cancer sites, was calculated. Additionally, lifetime risk was calculated from the ages of 40, 50, 60, and 70 years to death, assuming the probability of being alive and cancer free at those ages equals 1.

The Z test was used to examine the difference between groups, with the statistic Z calculated by the formula: $z = \frac{|S_1 - S_2|}{\sqrt{s.e.(S_1)^2 + s.e.(S_2)^2}}$, where S_1 indicates the lifetime risk in group 1, S_2 indicates the lifetime risk in group 2, $s.e.(S_1)$ indicates the standard error of S_1, $s.e.(S_2)$indicates the standard error of S_2. A P-value is considered significant if <0.05 for $Z > 1.96$ and <0.01 for $Z > 2.56$.[15]

The risk ratio for gender was calculated by dividing the lifetime risk in men by the lifetime risk in women. The geographical risk ratio was computed by dividing the urban lifetime risk by the rural lifetime risk.[16] Annual percent changes (APCs) for lifetime risk of developing and dying from cancer from 2010 to 2020, overall and stratified by gender and cancer sites, were estimated using the log-linear model. Sensitivity analyses were conducted by comparing the lifetime risks with the cumulative risks for the age group of 0–74 years (Fig. 1). All analysis was performed using R software (version 4.3).

3. Results

3.1. Estimated lifetime risk of developing and dying from cancer overall

Table 1 presents the estimated lifetime risk of developing and dying from cancer in 2020, overall and stratified by area and gender. The overall risks were 30.19 % for developing cancer and 23.62 % for dying from it. These risks were higher in urban populations compared to rural ones, and higher in men compared to women.

3.2. Leading cancer sites for lifetime risk of developing and dying from cancer

The lifetime risk of developing cancer varied by cancer sites, with the highest risks observed for lung (6.94 %), breast (4.14 %), stomach (3.95 %), esophagus (3.75 %), and liver (2.86 %) (Table 2). When stratified by gender, lung cancer was the leading site for both men and women. For men, the subsequent sites were stomach, esophagus, liver, and colorectum. For women, they were breast, esophagus, stomach, and colorectum. In urban areas, the leading cancer sites were lung, breast, stomach, colorectum, and liver. In rural areas, they were lung, esophagus, stomach, breast, and liver. (Table 2)

The top five cancer sites for the lifetime risk of dying from cancer were lung (5.99 %), stomach (3.60 %), esophagus (3.39 %), liver (2.78 %), and colorectum (1.55 %). For men, the ranking was consistent with the overall trend. For women, esophagus was the second leading site, followed by stomach. In rural areas, the ranking was consistent with the overall trend, whereas in urban areas, liver ranked third and esophagus fourth (Table 2).

Lifetime risk of developing and dying from gastrointestinal cancers, including stomach, esophageal, liver, colorectum, gallbladder, and pancreas cancers, accounted for 47.60 % and 52.76 % of the overall incidence and mortality risks, respectively.

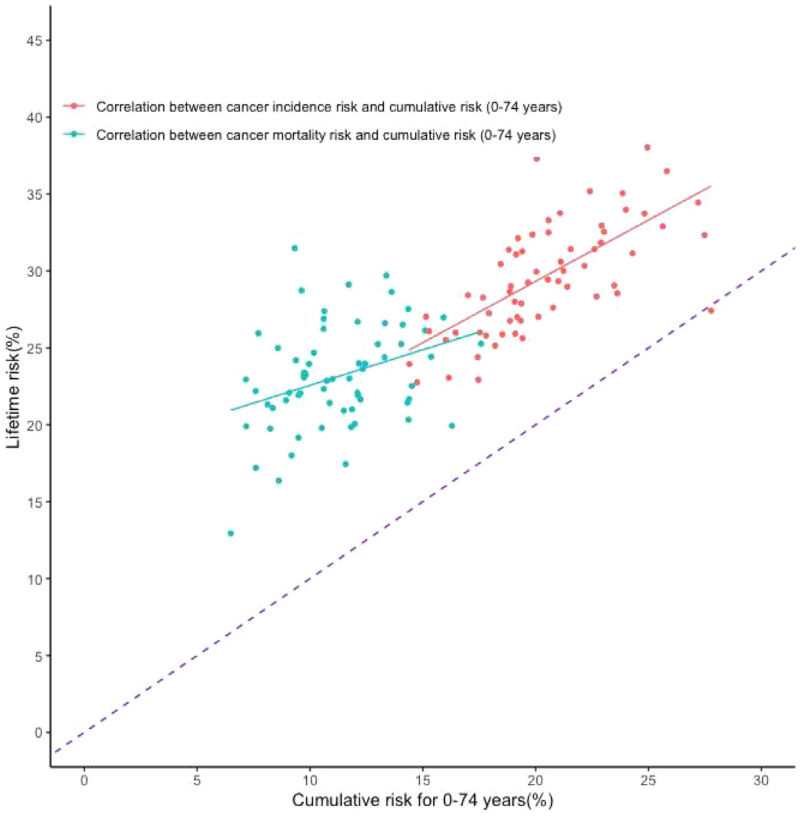

Fig. 1. Correlation between lifetime risk of developing and dying from cancer and traditional cumulative risk for 0–74 years. The blue dots indicates the correlation between lifetime risk of developing cancer and cumulative incidence risk for 0–74 years; the red dots indicates the correlation between lifetime risk of dying from cancer and cumulative mortality risk for 0–74 years.

Table 1
The overall lifetime risk of developing and dying from cancer in 2020 among residents in Henan, China.

Variable	Men, % (95 % CI)	Women, % (95 % CI)	Both genders, % (95 % CI)
Developing			
All	31.22 (30.59–31.85)	29.02 (28.12–29.91)	30.19 (29.63–30.76)
Urban areas	33.00 (31.68–34.32)	30.74 (29.08–32.40)	32.01 (30.87–33.15)
Rural areas	30.50 (29.79–31.22)	28.30 (27.25–29.35)	29.46 (28.82–30.11)
Dying			
All	26.73 (26.29–27.16)	20.08 (19.51–20.64)	23.62 (23.28–23.95)
Urban areas	27.64 (26.77–28.51)	20.92 (19.77–22.08)	24.53 (23.86–25.20)
Rural areas	26.37 (25.86–26.87)	19.78 (19.14–20.43)	23.29 (22.90–23.67)

3.3. Gender difference in lifetime risk

Significant gender differences were observed in the lifetime risk of developing cancers other than colorectal, pancreatic, and bone cancers, and leukemia. Men had a higher overall risk of developing cancer compared to women. For most cancer sites, men had higher risks, except for thyroid, gallbladder, brain, and pancreatic cancers, where the risk ratios were 0.29, 0.69, 0.83, and 0.91, respectively. The overall risk in men was 8 % higher than in women, with risk ratios ranging from 1.12 for lymphoma to 6.75 for larynx cancer. For common sites like lung, stomach, esophagus, and liver, the risk ratios were 1.77, 1.89, 1.30, and 1.58, respectively (Table 3).

Men also had a 33 % higher overall risk of dying from cancer compared to women. Significant gender differences were noted in the oral cavity, nasopharyngeal, esophageal, stomach, liver, gallbladder, laryngeal, lung, kidney, and bladder cancers. Among these, only gallbladder cancer had a higher mortality risk in women (Table 3).

3.4. Geographical differences in lifetime risk

Geographical differences were observed, with a 9 % higher risk of developing cancer in urban areas compared to rural areas. Most cancer sites showed higher risks in urban areas, except for esophageal, stomach, and liver cancers, which had higher risks in rural areas, with risk ratios of 0.60, 0.81, and 0.90, respectively (Table 4).

There was no significant difference in the lifetime risk of dying from cancer between urban and rural areas. However, the lifetime risk for esophageal, stomach, and liver cancers was higher in rural areas, whereas the risks for oral, colorectal, gallbladder, pancreatic, lung, ovary, prostate, kidney, and bladder cancers were higher in urban areas (Table 4).

3.5. Lifetime risk according to age at diagnosis

The lifetime risk of developing cancer from ages 40, 50, 60, and 70 years onward is presented in Table 5. The risks remained relatively stable until age 50 years, then gradually decreased, with a remaining risk of 15.87 % (95 % CI: 15.67 %–16.08 %) from age 70 years onward. The lifetime risk of dying from cancer also decreased with age, with a remaining risk of 16.93 % (95 % CI: 16.72 %–17.14 %) from age 70 years onward (Table 5).

3.6. Temporal trends in lifetime risk

From 2010 to 2020, the overall lifetime risk of developing cancer increased by 0.75 %. Notable increases were observed in thyroid,

Table 2
Lifetime risk of developing and dying from cancer stratified by cancer sites.

Variable	All	Gender		Area	
		Men	Women	Urban	Rural
Developing, **% (95% CI)**					
All Sites	30.19 (29.63–30.76)	31.22 (30.59–31.85)	29.02 (28.12–29.91)	32.01 (30.87–33.15)	29.46 (28.82–30.11)
Lung	6.94 (6.82–7.06)	8.73 (8.56–8.90)	4.92 (4.76,5.09)	7.21 (6.97–7.45)	6.83 (6.70–6.97)
Breast[a]	4.14 (3.72–4.56)	–	4.14 (3.72–4.56)	4.97 (4.08–5.87)	3.80 (3.32–4.27)
Stomach	3.95 (3.87–4.03)	5.08 (4.96–5.19)	2.69 (2.59–2.79)	3.37 (3.23–3.50)	4.18 (4.09–4.27)
Esophagus	3.75 (3.67–3.82)	4.21 (4.10–4.31)	3.23 (3.13–3.34)	2.54 (2.43–2.66)	4.21 (4.12–4.31)
Liver	2.86 (2.79–2.93)	3.47 (3.37–3.57)	2.19 (2.11–2.28)	2.66 (2.54–2.79)	2.94 (2.86–3.02)
Colorectal	2.55 (2.49–2.61)	2.59 (2.51–2.67)	2.50 (2.40–2.59)	3.33 (3.20–3.47)	2.24 (2.17–2.30)
Cervix Uteri	1.85 (1.65–2.06)	–	1.85 (1.65–2.06)	1.76 (1.35–2.18)	1.89 (1.65–2.13)
Thyroid	1.33 (1.21–1.44)	0.61 (0.55–0.67)	2.08 (1.70–2.46)	2.12 (1.69–2.54)	1.00 (0.91–1.09)
Prostate	1.24 (1.18–1.30)	1.24 (1.18–1.30)	–	1.95 (1.81–2.10)	0.96 (0.90–1.02)
Uterus	0.97 (0.90–1.04)	–	0.97 (0.90–1.04)	1.04 (0.88–1.20)	0.94 (0.86–1.03)
Ovary	0.74 (0.66–0.83)	–	0.74 (0.66–0.83)	0.79 (0.63–0.95)	0.73 (0.62–0.83)
Brain[b]	0.70 (0.65–0.75)	0.64 (0.58–0.70)	0.77 (0.69–0.84)	0.63 (0.53–0.72)	0.73 (0.67–0.78)
Pancreas	0.64 (0.61–0.67)	0.61 (0.57–0.65)	0.67 (0.63–0.72)	0.88 (0.81–0.95)	0.55 (0.52–0.58)
Gallbladder	0.62 (0.59–0.65)	0.51 (0.47–0.54)	0.74 (0.69–0.79)	0.78 (0.72–0.85)	0.55 (0.52–0.59)
Bladder	0.60 (0.57–0.63)	0.89 (0.84–0.94)	0.28 (0.25–0.31)	0.83 (0.77–0.90)	0.51 (0.48–0.54)
Lymphoma	0.53 (0.50–0.55)	0.55 (0.52–0.59)	0.49 (0.45–0.53)	0.75 (0.68–0.81)	0.44 (0.41–0.47)
Kidney	0.49 (0.47–0.51)	0.56 (0.53–0.60)	0.41 (0.38–0.44)	0.66 (0.61–0.71)	0.42 (0.40–0.45)
Leukemia	0.46 (0.39–0.52)	0.47 (0.39–0.55)	0.44 (0.34–0.53)	0.56 (0.40–0.71)	0.42 (0.35–0.48)
Oral	0.38 (0.36–0.40)	0.44 (0.41–0.47)	0.31 (0.28–0.34)	0.48 (0.43–0.53)	0.34 (0.32–0.36)
Bone	0.23 (0.20–0.25)	0.23 (0.20–0.26)	0.22 (0.18–0.26)	0.20 (0.15–0.26)	0.24 (0.21–0.26)
Larynx	0.16 (0.15–0.18)	0.27 (0.25–0.30)	0.04 (0.03–0.06)	0.20 (0.17–0.23)	0.15 (0.13–0.17)
Nasopharynx	0.09 (0.08–0.10)	0.12 (0.10–0.13)	0.07 (0.05–0.08)	0.08 (0.06–0.09)	0.10 (0.09–0.11)
Testis	0.03 (0.02–0.04)	0.03 (0.02–0.04)	–	0.02 (0.01–0.04)	0.03 (0.02–0.04)
Dying, **% (95% CI)**					
All Sites	23.62 (23.28–23.95)	26.73 (26.29–27.16)	20.08 (19.51–20.64)	24.53 (23.86–25.20)	23.29 (22.90–23.67)
Lung	5.99 (5.89–6.09)	7.81 (7.66–7.97)	3.93 (3.81–4.05)	6.35 (6.14–6.55)	5.86 (5.74–5.97)
Stomach	3.60 (3.52–3.67)	4.58 (4.46–4.69)	2.49 (2.40–2.58)	3.08 (2.95–3.22)	3.80 (3.71–3.89)
Esophagus	3.39 (3.32–3.47)	3.86 (3.75–3.96)	2.86 (2.76–2.96)	2.51 (2.39–2.64)	3.73 (3.64–3.82)
Liver	2.78 (2.71–2.84)	3.34 (3.24–3.44)	2.16 (2.08–2.25)	2.65 (2.52–2.77)	2.83 (2.75–2.90)
Colorectal	1.55 (1.50–1.60)	1.57 (1.50–1.63)	1.53 (1.45–1.60)	1.99 (1.88–2.10)	1.38 (1.33–1.44)
Breast[a]	1.20 (1.13–1.26)	–	1.20 (1.13–1.26)	1.53 (1.38–1.69)	1.07 (1.00–1.14)
Cervix Uteri	0.72 (0.68–0.77)	–	0.72 (0.68–0.77)	0.70 (0.61–0.79)	0.73 (0.68–0.79)
Prostate	0.67 (0.62–0.72)	0.67 (0.62–0.72)	–	1.11 (0.99–1.23)	0.50 (0.45–0.55)
Pancreas	0.59 (0.56–0.62)	0.57 (0.53–0.60)	0.62 (0.57–0.66)	0.83 (0.76–0.90)	0.50 (0.47–0.53)
Gallbladder	0.55 (0.53–0.58)	0.43 (0.40–0.47)	0.69 (0.64–0.74)	0.71 (0.64–0.77)	0.50 (0.47–0.53)
Brain[b]	0.52 (0.49–0.55)	0.52 (0.47–0.56)	0.53 (0.47–0.58)	0.49 (0.42–0.55)	0.53 (0.50–0.57)
Ovary	0.41 (0.38–0.45)	–	0.41 (0.38–0.45)	0.57 (0.49–0.65)	0.35 (0.32–0.39)
Lymphoma	0.33 (0.31–0.36)	0.35 (0.32–0.38)	0.31 (0.28–0.34)	0.45 (0.40–0.50)	0.29 (0.27–0.31)
Bladder	0.32 (0.30–0.34)	0.46 (0.42–0.50)	0.16 (0.13–0.18)	0.43 (0.37–0.48)	0.28 (0.26–0.31)
Leukemia	0.31 (0.28–0.33)	0.33 (0.30–0.36)	0.28 (0.24–0.32)	0.41 (0.36–0.47)	0.27 (0.24–0.29)
Kidney	0.28 (0.26–0.30)	0.32 (0.29–0.35)	0.22 (0.20–0.25)	0.39 (0.34–0.43)	0.23 (0.21–0.25)
Uterus	0.27 (0.24–0.30)	–	0.27 (0.24–0.30)	0.29 (0.24–0.35)	0.26 (0.23–0.30)
Oral	0.21 (0.19–0.23)	0.25 (0.22–0.27)	0.17 (0.15–0.20)	0.27 (0.23–0.31)	0.19 (0.17–0.21)
Bone	0.17 (0.16–0.19)	0.19 (0.17–0.21)	0.15 (0.13–0.18)	0.16 (0.13–0.19)	0.18 (0.16–0.20)
Larynx	0.11 (0.10–0.12)	0.17 (0.15–0.20)	0.04 (0.02–0.05)	0.13 (0.10–0.16)	0.10 (0.09–0.11)
Thyroid	0.10 (0.09–0.12)	0.06 (0.05–0.08)	0.15 (0.13–0.17)	0.12 (0.09–0.14)	0.10 (0.09–0.11)
Nasopharynx	0.06 (0.05–0.07)	0.08 (0.06–0.09)	0.05 (0.04–0.06)	0.06 (0.04–0.08)	0.06 (0.05–0.07)
Testis	0.01 (0.01–0.02)	0.01 (0.01–0.02)	–	0.01 (0–0.01)	0.01 (0.01–0.02)

[a] Life time risk was calculated for women;
[b] Brain is short for brain,and central nervous system. – Data is not available for the calculation of lifetime risk.

prostate, lymphoma, kidney, and gallbladder cancers, with APCs of 20.95 %, 11.38 %, 10.97 %, 6.85 %, and 6.10 %, respectively. Decreasing trends were seen in nasopharyngeal, esophageal, stomach, and liver cancers, with APCs of -4.59 %, -3.07 %, -2.42 %, and -1.60 %, respectively (Table 6, Fig. 2).

The observed increasing trend in the overall lifetime cancer mortality risk was not statistically significant. However, stomach, esophageal, and liver cancers showed decreasing trends, with APCs of -1.77 %, -1.71 %, and -1.5 %, respectively. In contrast, thyroid, lymphoma, kidney, prostate, and gallbladder cancers exhibited increasing trends, with APCs of 16.88 %, 12.78 %, 10.50 %, 9.15 %, and 8.37 %, respectively (Table 6, Fig. 2).

Major cancer sites like lung, breast, and colorectum showed rising trends in both the lifetime risk of developing and dying from cancer. The APCs for developing these cancers were 1.27 %, 3.83 %, and 3.45 %, respectively, while the APCs for dying from them were 1.08 %, 1.8 %, and 2.92 %, respectively. Conversely, esophagus, stomach, and liver cancers showed decreasing trends for both developing and dying from cancer (Table 6, Fig. 2).

4. Discussion

To better understand the regional differences in cancer burden in China, we estimated the lifetime risk of developing and dying from cancer among residents of Henan Province, located in central China. Our aim was to explore the variations and trends in these risks across genders, regions, and ages. This study found that the lifetime risks of developing and dying from cancer in Henan, China, were 30.19 % and 23.62 %, respectively, with notable differences observed by gender and geography. The top five sites for the highest lifetime risk of developing cancer were the lungs, breast, stomach, esophagus, and liver. For dying from cancer, the top five sites were the lungs, stom-

Table 3
Gender risk ratio between men and women for lifetime risk of developing and dying from cancer.[a]

Site	Developing cancer			Dying from cancer		
	Both regions	Urban	Rural	Both regions	Urban	Rural
All Sites	1.08[d]	1.07[c]	1.08[d]	1.33[d]	1.32[d]	1.33[d]
Larynx	6.75[d]	8.50[d]	4.80[d]	4.25[d]	5.25[d]	4.00[d]
Bladder	3.18[d]	3.74[d]	2.96[d]	2.88[d]	3.26[d]	2.67[d]
Stomach	1.89[d]	2.06[d]	1.84[d]	1.84[d]	1.81[d]	1.85[d]
Lung	1.77[d]	1.76[d]	1.78[d]	1.99[d]	1.99[d]	1.98[d]
Nasopharynx	1.71[d]	2.75[d]	1.71[d]	1.60[d]	2.00[c]	1.40
Liver	1.58[d]	1.76[d]	1.52[d]	1.55[d]	1.61[d]	1.52[d]
Oral	1.42[d]	1.59[d]	1.31[d]	1.47[d]	1.35	1.47[d]
Kidney	1.37[d]	1.43[d]	1.33[d]	1.45[d]	1.48[d]	1.42[d]
Esophagus	1.30[d]	1.42[d]	1.27[d]	1.35[d]	1.42[d]	1.33[d]
Lymphoma	1.12[c]	1.10	1.17[c]	1.13	0.96	1.23[d]
Leukemia	1.07	1.20	1.02	1.18	1.41	1.04
Bone	1.05	1.28	0.96	1.27[c]	0.94	1.33[d]
Colorectal	1.04	1.07	1.01	1.03	1.12[c]	0.97
Pancreas	0.91	0.84[c]	0.95	0.92	0.80[d]	1.00
Brain[b]	0.83[d]	0.85	0.82[c]	0.98	1.16	0.91
Gallbladder	0.69[d]	0.74[d]	0.65[d]	0.62[d]	0.66[d]	0.60[d]
Thyroid	0.29[d]	0.34[d]	0.27[d]	0.40[d]	0.41[d]	0.40[d]

[a] The gender risk ratio of lifetime cancer risk is calculated by dividing the lifetime risk value for males by the lifetime risk value for females.
[b] Brain is short for brain–and central nervous system.
[c] The risk ratio is significantly different from 1 ($P < 0.05$).
[d] The risk ratio is significantly different from 1 ($P < 0.01$).

Table 4
Area risk ratio between urban and rural areas for lifetime risk of developing and dying from cancer.[c]

	Developing cancer			Dying from cancer		
	Both genders	Men	Women	Both genders	Men	Women
All Sites	1.09[e]	1.08[e]	1.09[d]	1.05[e]	1.05[d]	1.06
Thyroid	2.12[e]	2.49[e]	1.98[e]	1.20	1.17	1.13
Prostate	2.03[e]	2.03[e]	–	2.22[e]	2.22[e]	–
Lymphoma	1.70[e]	1.66[e]	1.77[e]	1.55[e]	1.38[e]	1.77[e]
Bladder	1.63[e]	1.72[e]	1.36[d]	1.54[e]	1.55[e]	1.27
Pancreas	1.60[e]	1.53[e]	1.71[e]	1.66[e]	1.48[e]	1.86[e]
Kidney	1.57[e]	1.60[e]	1.50[e]	1.70[e]	1.70[e]	1.63[e]
Colorectal	1.49[e]	1.53[e]	1.45[e]	1.44[e]	1.54[e]	1.34[e]
Gallbladder	1.42[e]	1.52[e]	1.34[e]	1.42[e]	1.50[e]	1.38[e]
Oral	1.41[e]	1.55[e]	1.28[d]	1.42[e]	1.41[e]	1.53[e]
Larynx	1.33[e]	1.42[e]	0.80	1.30[d]	1.31	1.00
Leukemia	1.33	1.43	1.22	1.52[e]	1.78[e]	1.31
Breast[a]	1.31[d]	–	1.31[d]	1.43[e]	–	1.43[e]
Uterus	1.11	–	1.11	1.12	–	1.12
Ovary	1.08	–	1.08	1.63[e]	–	1.63[e]
Lung	1.06[e]	1.05[d]	1.07	1.08[e]	1.08[e]	1.08[d]
Cervix Uteri	0.93	–	0.93	0.96	–	0.96
Liver	0.90[e]	0.96	0.83[e]	0.94[d]	0.96	0.91[d]
Brain[b]	0.86	0.88	0.85	0.92	1.02	0.80
Bone	0.83	1.00	0.75	0.89	0.75[d]	1.07
Stomach	0.81[e]	0.84[e]	0.75[e]	0.81[e]	0.81[e]	0.82[e]
Nasopharynx	0.80	0.92	0.57[d]	1.00	1.14	0.80
Testis	0.67	0.67	–	1.00	1.00	–
Esophagus	0.60[e]	0.63[e]	0.57[e]	0.67[e]	0.69[e]	0.64[e]

[a] Life time risk was calculated for women.
[b] Brain is short for brain, and central nervous system.
[c] The area risk ratio of lifetime cancer risk is calculated by dividing the risk value for urban areas by the risk value for rural areas. – Data is not available for the calculation of lifetime risk.
[d] The risk ratio is significantly different from 1 ($P < 0.05$).
[e] The risk ratio is significantly different from 1 ($P < 0.01$).

ach, esophagus, liver, and colorectum. There is a shifting pattern in lifetime cancers, with gradually decreases in esophageal, stomach, and liver cancers, and increases in thyroid, prostate, and gallbladder cancers.

The lifetime risk of developing cancer in Henan was higher than the world average of 25.10 %, but slightly lower than the Eastern Asia average of 32.35 % according to GLOBOCAN 2020 data.[5] Lifetime cancer risk data are rare for the Chinese population, with the exception of a study in urban Shanghai that reported the risks for digestive system cancers.[7] Significant geographic difference in lifetime risk existed globally, with an increase observed in regions with higher Human Development Index (HDI) levels. Our results also showed a 9 % higher lifetime cancer risk in urban areas compared to rural areas, consistent across most cancers except esophageal, stomach, and liver

Table 5
Lifetime risk of developing and dying from cancer within selected age intervals in2020 among residents in Henan, China.

Variable	0-death	40 years–death	50 years–death	60 years–death	70 years–death
Developing, % (95% CI)					
All Sites	30.19 (29.63–30.76)	28.89 (28.46–29.32)	27.03 (26.66–27.40)	22.90 (22.61–23.20)	15.87 (15.67–16.08)
Oral	0.38 (0.36–0.40)	0.36 (0.34–0.38)	0.33 (0.31–0.36)	0.28 (0.26–0.30)	0.20 (0.19–0.22)
Nasopharynx	0.09 (0.08–0.10)	0.09 (0.08–0.10)	0.08 (0.07–0.09)	0.05 (0.05–0.06)	0.03 (0.02–0.04)
Esophagus	3.75 (3.67–3.82)	3.74 (3.66–3.81)	3.70 (3.63–3.78)	3.46 (3.38–3.53)	2.56 (2.49–2.62)
Stomach	3.95 (3.87–4.03)	3.91 (3.84–3.99)	3.83 (3.75–3.90)	3.47 (3.40–3.54)	2.49 (2.42–2.55)
Colorectal	2.55 (2.49–2.61)	2.50 (2.44–2.56)	2.39 (2.33–2.45)	2.08 (2.03–2.14)	1.46 (1.41–1.51)
Liver	2.86 (2.79–2.93)	2.81 (2.74–2.87)	2.64 (2.57–2.70)	2.22 (2.16–2.27)	1.52 (1.47–1.57)
Gallbladder	0.62 (0.59–0.65)	0.61 (0.58–0.64)	0.60 (0.57–0.63)	0.56 (0.53–0.59)	0.42 (0.40–0.45)
Pancreas	0.64 (0.61–0.67)	0.63 (0.60–0.66)	0.61 (0.58–0.64)	0.55 (0.53–0.58)	0.41 (0.38–0.43)
Larynx	0.16 (0.15–0.18)	0.16 (0.15–0.18)	0.16 (0.14–0.17)	0.13 (0.12–0.14)	0.08 (0.07–0.10)
Lung	6.94 (6.82–7.06)	6.89 (6.77–7.01)	6.70 (6.59–6.82)	5.97 (5.87–6.08)	4.30 (4.22–4.39)
Bone	0.23 (0.20–0.25)	0.19 (0.18–0.21)	0.18 (0.17–0.20)	0.15 (0.14–0.17)	0.11 (0.09–0.12)
Breast[a]	4.14 (3.72–4.56)	3.74 (3.43–4.05)	2.93 (2.76–3.11)	1.84 (1.76–1.92)	0.92 (0.87–0.98)
Cervix Uteri	1.85 (1.65–2.06)	1.68 (1.53–1.83)	1.37 (1.29–1.45)	0.88 (0.83–0.93)	0.47 (0.43–0.51)
Uterus	0.97 (0.90–1.04)	0.93 (0.86–1.00)	0.79 (0.74–0.85)	0.46 (0.43–0.50)	0.24 (0.21–0.27)
Ovary	0.74 (0.66–0.83)	0.65 (0.60–0.70)	0.55 (0.51–0.59)	0.38 (0.35–0.42)	0.22 (0.19–0.25)
Prostate	1.24 (1.18–1.30)	1.24 (1.18–1.30)	1.24 (1.18–1.30)	1.21 (1.15–1.27)	1.00 (0.94–1.05)
Testis	0.03 (0.02–0.04)	0.02 (0.01–0.03)	0.01 (0.01–0.02)	0.01 (0.01–0.02)	0.01 (0.00–0.01)
Kidney	0.49 (0.47–0.51)	0.47 (0.44–0.49)	0.44 (0.41–0.46)	0.36 (0.34–0.38)	0.23 (0.21–0.25)
Bladder	0.60 (0.57–0.63)	0.59 (0.57–0.62)	0.58 (0.55–0.61)	0.53 (0.50–0.55)	0.40 (0.37–0.43)
Brain[b]	0.70 (0.65–0.75)	0.62 (0.59–0.65)	0.57 (0.55–0.60)	0.47 (0.44–0.49)	0.32 (0.29–0.34)
Thyroid	1.33 (1.21–1.44)	1.00 (0.95–1.05)	0.70 (0.67–0.73)	0.34 (0.32–0.35)	0.12 (0.11–0.13)
Lymphoma	0.53 (0.50–0.55)	0.49 (0.47–0.51)	0.46 (0.43–0.48)	0.38 (0.36–0.41)	0.25 (0.23–0.27)
Leukemia	0.46 (0.39–0.52)	0.36 (0.34–0.38)	0.33 (0.31–0.35)	0.28 (0.26–0.30)	0.19 (0.17–0.21)
Dying, % (95% CI)					
All Sites	23.62 (23.28–23.95)	23.36 (23.05–23.68)	22.87 (22.57–23.18)	21.18 (20.91–21.44)	16.93 (16.72–17.14)
Oral	0.21 (0.19–0.23)	0.21 (0.19–0.23)	0.20 (0.19–0.22)	0.19 (0.17–0.21)	0.15 (0.14–0.17)
Nasopharynx	0.06 (0.05–0.07)	0.06 (0.05–0.07)	0.06 (0.05–0.07)	0.05 (0.04–0.06)	0.04 (0.03–0.04)
Esophagus	3.39 (3.32–3.47)	3.39 (3.31–3.46)	3.37 (3.30–3.44)	3.25 (3.18–3.33)	2.72 (2.65–2.79)
Stomach	3.60 (3.52–3.67)	3.58 (3.51–3.65)	3.54 (3.46–3.61)	3.35 (3.27–3.42)	2.70 (2.63–2.77)
Colorectal	1.55 (1.50–1.60)	1.54 (1.49–1.59)	1.51 (1.46–1.56)	1.41 (1.36–1.46)	1.17 (1.12–1.22)
Liver	2.78 (2.71–2.84)	2.74 (2.68–2.81)	2.63 (2.57–2.69)	2.31 (2.25–2.37)	1.71 (1.66–1.77)
Gallbladder	0.55 (0.53–0.58)	0.55 (0.52–0.58)	0.55 (0.52–0.58)	0.52 (0.49–0.55)	0.42 (0.40–0.45)
Pancreas	0.59 (0.56–0.62)	0.59 (0.56–0.62)	0.58 (0.55–0.61)	0.53 (0.50–0.56)	0.42 (0.39–0.45)
Larynx	0.11 (0.10–0.12)	0.11 (0.10–0.12)	0.11 (0.09–0.12)	0.10 (0.09–0.11)	0.08 (0.07–0.09)
Lung	5.99 (5.89–6.09)	5.97 (5.87–6.07)	5.89 (5.79–5.99)	5.48 (5.38–5.57)	4.36 (4.28–4.45)
Bone	0.17 (0.16–0.19)	0.16 (0.15–0.18)	0.16 (0.14–0.17)	0.14 (0.13–0.16)	0.12 (0.10–0.13)
Breast[a]	1.20 (1.13–1.26)	1.17 (1.11–1.24)	1.09 (1.03–1.15)	0.89 (0.84–0.95)	0.62 (0.57–0.67)
Cervix Uteri	0.72 (0.68–0.77)	0.71 (0.66–0.75)	0.66 (0.62–0.70)	0.55 (0.51–0.60)	0.40 (0.36–0.43)
Uterus	0.27 (0.24–0.30)	0.27 (0.24–0.30)	0.26 (0.23–0.29)	0.22 (0.20–0.25)	0.17 (0.15–0.20)
Ovary	0.41 (0.38–0.45)	0.40 (0.37–0.44)	0.38 (0.35–0.42)	0.32 (0.29–0.35)	0.24 (0.21–0.27)
Prostate	0.67 (0.62–0.72)	0.67 (0.62–0.72)	0.67 (0.62–0.71)	0.66 (0.61–0.71)	0.61 (0.57–0.66)
Testis	0.01 (0.01–0.02)	0.01 (0.00–0.01)	0.01 (0.00–0.01)	0.01 (0.00–0.01)	0.01 (0.00–0.01)
Kidney	0.28 (0.26–0.30)	0.27 (0.25–0.29)	0.27 (0.25–0.29)	0.25 (0.23–0.26)	0.20 (0.18–0.22)
Bladder	0.32 (0.30–0.34)	0.32 (0.30–0.34)	0.32 (0.29–0.34)	0.31 (0.28–0.33)	0.27 (0.25–0.30)
Brain[b]	0.52 (0.49–0.55)	0.48 (0.46–0.51)	0.46 (0.43–0.49)	0.41 (0.38–0.43)	0.31 (0.29–0.33)
Thyroid	0.10 (0.09–0.12)	0.10 (0.09–0.11)	0.10 (0.09–0.11)	0.09 (0.08–0.10)	0.07 (0.06–0.08)
Lymphoma	0.33 (0.31–0.36)	0.32 (0.30–0.35)	0.31 (0.29–0.33)	0.28 (0.26–0.30)	0.21 (0.19–0.23)
Leukemia	0.31 (0.28–0.33)	0.27 (0.25–0.29)	0.26 (0.24–0.28)	0.23 (0.21–0.25)	0.17 (0.15–0.19)

[a] Life time risk was calculated for women.
[b] Brain is short for brain,and central nervous system.

cancers. These regional differences highlight the need for targeted cancer prevention and control efforts.

Lung cancer was the leading cancer threatening residents' health in the population, with individuals facing a 6.94 % probability of developing lung cancer and a 5.99 % probability of dying from it over their lifetime. A nationwide low-dose CT (LDCT) screening program for lung cancer in urban China was initiated in 2013 to alleviate the lung cancer burden, despite a lack of evidence from large randomized controlled trials (RCTs) in the Chinese population.[17,18] A 31 % reduction in lung cancer mortality was found for participants in the screened group compared with those in the non-screened group.[18] This provided important evidence on the effectiveness of LDCT screening for lung cancer in the Chinese population and may help optimize lung cancer screening programs to improve screening effectiveness. Our results suggested that individuals aged 50 and above contribute to 96.54 % of the overall lifetime cancer risk, with those aged 80 and above contributing 29.68 % of the remaining risk. Therefore, the risk for ages 50–79 accounts for 66.86 % of the total risk. This finding may provide clues for research aimed at optimizing the initial age for lung cancer screening. Furthermore, the lifetime risk of developing lung cancer continues to show an upward trend, with an APC of 1.27 %. This increase may be associated with ineffective tobacco control strategies,[19,20] as smoking has been identified as the predominant factor, accounting for 63.73 % of lung cancer cases.[21] These findings suggest that, in addition to implementing screening-based control measures, we should also strengthen primary prevention measures for targeting the main risk factors of lung cancer.

China is among the countries with a high lifetime risk of gastrointestinal cancers,[6] accounting for approximately half of the overall cancer risk, as revealed by our results. Stomach, esophageal, liver, and colorectal cancer were among the top 10 cancer sites in terms of lifetime incidence and mortality risk. Screening programs have been conducted in high-risk and urban areas nationwide in China to reduce the burden of these cancers.[22] Upper gastrointestinal cancer screening has been verified as effective, showing a significant decrease in incidence and mortal-

Table 6
APC for Lifetime risk of developing and dying from cancer during 2010–2020.

Sites	Developing cancer, %			Dying from cancer, %		
	Men	Women	Both genders	Men	Women	Both genders
All Sites	0.30	1.36[d]	0.75[c]	0.56	0.55	0.56
Oral	4.05[d]	3.20[c]	3.74[d]	5.08[d]	3.79	4.04[c]
Nasopharynx	−3.63[c]	−5.38[c]	−4.59[c]	−0.76	−3.94	−1.97
Esophagus	−3.05[d]	−3.10[d]	−3.07[d]	−1.43[d]	−2.10[d]	−1.71[d]
Stomach	−2.20[d]	−2.75[d]	−2.42[d]	−1.33[c]	−2.60[d]	−1.77[c]
Colorectal	2.99[d]	3.96[d]	3.45[d]	2.93[d]	2.92[c]	2.92[d]
Liver	−1.80[d]	−1.19	−1.60[d]	−1.74[c]	−1.03	−1.50[c]
Gallbladder	6.22[d]	6.08[d]	6.10[d]	9.34[d]	7.78[d]	8.37[d]
Pancreas	1.70[d]	5.38[d]	3.16[d]	2.28[c]	5.45[d]	3.85[d]
Larynx	1.69[c]	−5.58[c]	0.24	0.86	−8.28[d]	−2.06
Lung	1.36[d]	1.14[d]	1.27[d]	1.50[c]	0.29	1.08[c]
Bone	−1.29[c]	−0.27	−1.05	−0.51	1.15	0.29
Breast[a]	–	3.83[d]	3.83[d]	–	1.80[c]	1.80[c]
Cervix Uteri	–	5.50[d]	5.50[d]	–	3.82[c]	3.82[c]
Uterus	–	2.88[c]	2.88[c]	–	0.93	0.93
Ovary	–	3.08[d]	3.08[d]	–	7.55[d]	7.55[d]
Prostate	11.38[d]	–	11.38[d]	9.15[d]	–	9.15[d]
Testis	1.62	–	1.62	−15.01	–	−15.01
Kidney	6.77[d]	7.24[d]	6.85[d]	8.63[d]	13.48[d]	10.50[d]
Bladder	4.45[d]	2.53	4.08[d]	2.80	3.64[c]	3.15[c]
Brain[b]	0.40	1.27	0.75	3.09[c]	4.22[d]	3.46[d]
Thyroid	18.41[d]	21.65[d]	20.95[d]	14.03[d]	15.90[d]	16.88[d]
Lymphoma	10.71[d]	11.23[d]	10.97[d]	12.37[d]	12.84[d]	12.78[d]
Leukemia	2.05[c]	1.51	1.76[c]	2.26	2.12	2.14

[a] Life time risk was calculated for women.
[b] Brain is short for brain, and central nervous system; –Data is not available for the calculation of lifetime risk.
[c] The APC is significantly different from 0 ($P < 0.05$).
[d] The APC is significantly different from 0 ($P < 0.01$).

ity in the screening group in high risk areas.[23,24] A decreasing trend in the lifetime risk of developing and dying from stomach, esophageal, and liver cancer was also observed in our results, consistent with the incidence and mortality trends published by the National Cancer Center.[25] This may reflect the achievements of cancer control policies, including but not limited to screening programs and the control of main risk factors such as H.pylori and hepatitis B.[26] Meanwhile, the impact of altered cancer risk due to factors including life style, population ageing, and environmental factors brought about economic and social development should be taken into account.[27–29] Notably, colorectal cancer has faced a rising lifetime risk despite the implementation of screening programs,[30] which aligns with trends observed in most low- and middle-income countries worldwide.[31] This may be due to the changing prevalence of underlying risk factors driven by rapid social and economic changes.[32]

Gender disparity was observed in most shared cancer sites, with lifetime risk being higher in men than in women, except for thyroid, brain and gallbladder cancers. This male predominance was seen across populations worldwide,[5,33] including in the childhood population.[34] This disparity cannot be explained solely by risk factors; gender-related biological factors must be considered.[33,35–37] Therefore, gender differences should be taken into account in cancer prevention and control.

The lifetime risk of developing and dying from gastrointestinal cancers, including gastric, esophageal, and liver cancers, were gradually declining. However, the risks of common cancers in developed countries, such as thyroid, prostate, and gallbladder cancer, were increasing in the Chinese population, with breast and cervix cancers also increasing. China is currently undergoing a transitional period of changing cancer patterns,[38,39] signifying increased challenges in cancer prevention and control.[25] This change maybe associated with the altered prevalence of risk factors due to increased socioeconomic development, and certain issues need to be addressed during this transitional process. The rapid increase in thyroid cancer poses a challenge in terms of over-diagnosis.[40,41] Although rural areas were less affected by over-diagnosis than urban ones, it remains a concern due to the accelerating urbanization in China.[40] The over-diagnosis of thyroid cancer not only imposes a significant burden on individual patients but also contributes to increasing national healthcare costs. Therefore, caution should be exercised in its diagnosis and treatment.[42] High-quality research is particularly needed to distinguish slowly progressing thyroid cancers from those that progress rapidly with a poorer prognosis.[43]

The study has several strengths. Firstly, the AMP method was used to estimate the lifetime cancer risk, allowing for the adjustment of the impact of multiple primary cancers. This method directly utilized frequency data from PBCR.[3] Secondly, the results were obtained by pooling high-quality data from 55 cancer registries, ensuring a reflection of the actual cancer incidence and mortality in the population. Thirdly, the study assessed cross-sectional estimates and the trend of lifetime risk, both overall and stratified by gender and cancer sites. This comprehensive analysis provides valuable insights into the current status and changing trends in risk, serving as a basis for future adjustments in cancer prevention and control policies.

Several limitations should be considered when interpreting the results. Firstly, the lifetime risk is estimated by projecting the cancer incidence and all-cause mortality rates at various ages in 2020 onto a cohort as they age. This estimation assumes that the age-specific rates and overall mortality rate remain stable over an extended period of time.[4] Secondly, the study only analyzed data from Henan Province, which could not represent the overall situation in other regions of China. Therefore, the conclusions of the article have limitations when generalized to other regions of China.

In conclusion, the lifetime risk of developing and dying from cancer in Henan, China was 30.19 % and 23.62 %, respectively. Lung, breast, and gastrointestinal cancers emerged as the types with the highest lifetime cancer risk. The pattern of lifetime cancer risk has been changing, characterized by a gradual decrease in esophageal, stomach, and liver cancers, but an relatively fast increase in thyroid, prostate, and gallbladder cancers. This study offers valuable insights for implementing cancer control interventions in China.

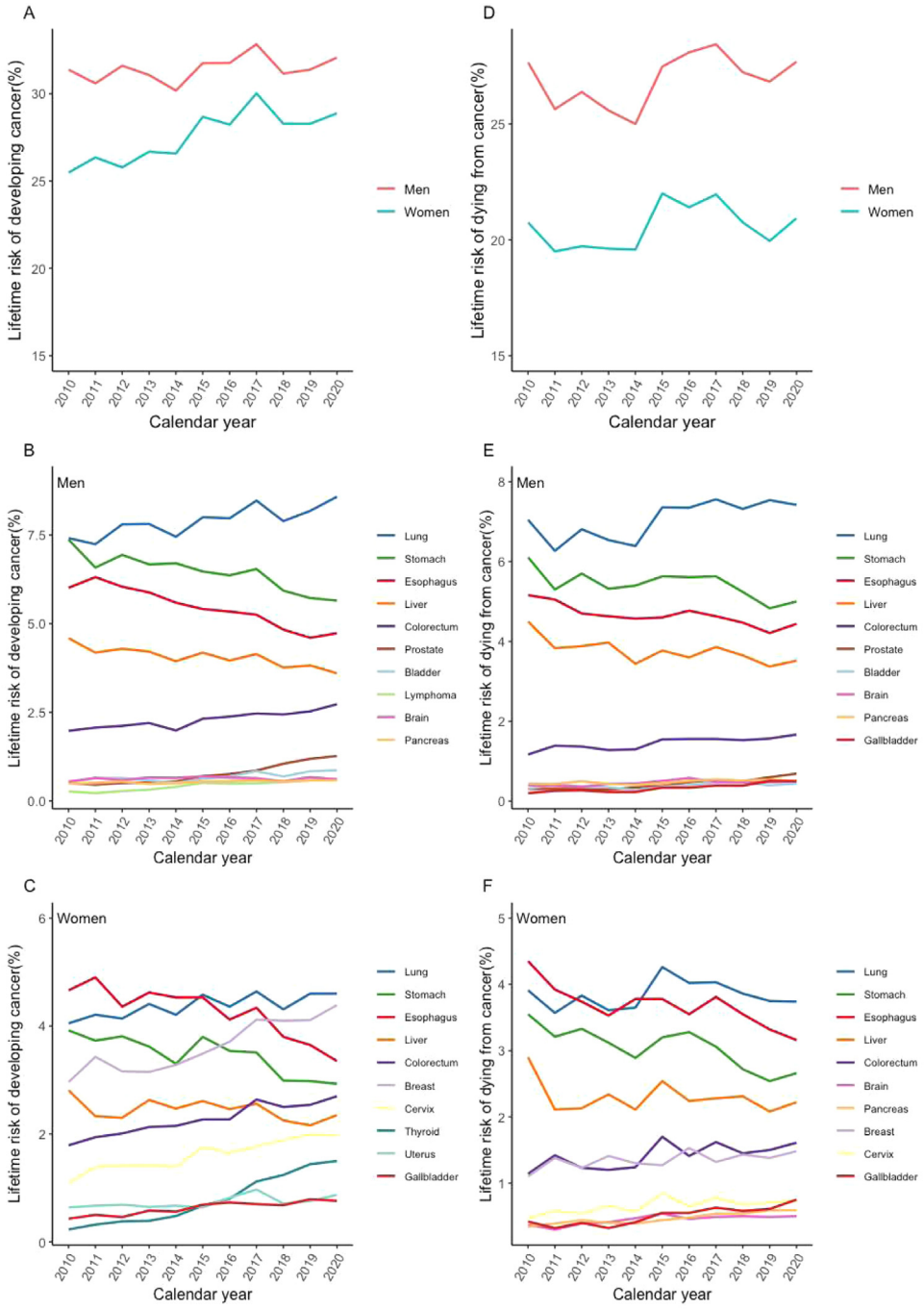

Fig. 2. Trends for lifetime risk of developing cancer and dying from cancer from 2010 to 2020, stratified by gender, and major site. (A, D) The temporal trends of overall cancer risk (A) and overall cancer mortality risk (D). (B, C) The temporal trends of lifetime cancer risk for major cancer types in males (B) and females (D). (E, F) The temporal trends of lifetime mortality risk for major cancer types in males (E) and females (F).

Declaration of completing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

S.Z. and Q.C. conducted the conceptualization. Q.C., S.L., Y.L., and H.L. performed the data curation, analysis, and methodology. Q.C. wrote the original draft. H.W., L.G., H.X., X.G., X.W., R.K., and L.Z. reviewed and edited the manuscript. S.Z. conducted the project administration and supervision. The manuscript has been read and approved by all the authors.

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