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Pancreatic cancer mortality in China from 2004 to 2021: an in-depth analysis of age, gender, and regional disparities

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Abstract

Objective This study aimed to analyze the trends and epidemiological characteristics of pancreatic cancer (PC) mortality in China from 2004 to 2021, focusing on gender, age, and regional disparities. The goal was to provide a comprehensive understanding of PC mortality and identify key risk factors to support future prevention and control strategies.

Methods Using data from the national Disease Surveillance Point (DSP) system, which covers a large and representative sample of the Chinese population, the study examined pancreatic cancer mortality trends across different age groups, sexes, and regions. Statistical analyses, including the independent-sample t-test and age-period-cohort (APC) model, were employed to assess mortality differences and annual percentage changes from 2004 to 2021.

Results The study recorded a significant increase in pancreatic cancer mortality, particularly among males and older adults. Mortality was consistently higher in urban areas, but the growth rate in rural areas surpassed that of urban areas. Regional disparities were also observed, with the eastern region showing the highest mortality rates but slower increases compared to the central and western regions. Key risk factors, including aging, diabetes, smoking, and chronic pancreatitis, were identified, with gender-specific differences linked to lifestyle factors such as smoking and alcohol consumption.

Conclusion Pancreatic cancer mortality in China has shown significant increases over the past 18 years, especially among males, older adults, and rural populations. The findings highlight the urgent need for targeted public health interventions to address gender- and age-specific risks, as well as healthcare access inequalities in less developed regions. Future research should focus on gathering more granular, individual-level data to better understand the complex interplay of risk factors and inform more effective prevention and treatment strategies.

Keywords Pancreatic cancer, Epidemiology, Mortality trends, Risk factors, China

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Introduction

Pancreatic Cancer (PC) is the 12th most common malignant tumor worldwide [1] and is known for its extreme aggressiveness and high lethality [2]. In China, the incidence and mortality rate of pancreatic cancer are on the rise [3]. Despite the continuous progress of medical technology and treatment methods, the prognosis of patients with pancreatic cancer is still poor due to the lack of obvious early symptoms and effective early screening methods [4–5]. Therefore, it is particularly important to deeply understand the epidemiological characteristics of pancreatic cancer mortality.

Although existing studies [6–7] reveal some features of the epidemiology of pancreatic cancer in China, including overall trends and regional differences at the national level, these studies rely on periodic statistics. Such data may not capture fully annual fluctuations and long-term changes in pancreatic cancer mortality due to large intervals and relatively short time spans. Therefore, more detailed, continuous and multi-dimensional data analysis is needed to reveal the dynamic changes and regional characteristics of pancreatic cancer mortality, and provide a more solid foundation for exploring new treatment options and prevention and control models.

Using a more continuous and extensive Chinese disease Surveillance Point (DSP) system, we compiled continuous data covering nearly 18 years from 2004 to 2021. Multi-dimensional analysis of large-scale, long-term data allows us to delve into the specific characteristics of pancreatic cancer mortality by age, sex and region. This study not only explains the epidemiology of pancreatic cancer mortality, but also provides a comprehensive and in-depth scientific basis for formulating more accurate public health policies. The breadth and depth of our methodology and data coverage allow us to provide more comprehensive insights to support future strategies and policies for pancreatic cancer prevention and control.

Methods

Data sources

China disease surveillance point (DSP) system is a sample-based mortality surveillance system, which was established in 1978 and has been a representative national mortality surveillance project since 2004. The monitoring system was integrated into China's life-scale system in 2013, expanding to 605 monitoring points, covering 324 million urban and rural people. Due to the difficulty of avoiding underreporting, we cleaned the collected data, compared and evaluated the collation quality and data quality of each monitoring point, and excluded data from certain monitoring points with severe underreporting that could potentially affect the overall results, thus forming the final database. To ensure the quality and reliability of the data, all data were subjected to quality assessment before being analyzed and used to generate results.

Statistical analysis

The patients were divided into 5 groups according to their ages: 20–44 years, 45–59 years, 60–74 years, 75–84 years and ≥ 85 years. R 3.1.27 and SAS 9.4 were used for analysis. The study looked at mortality rates by sex, year and region between 2004 and 2021 and examined differences between sex and between urban and rural areas by age group. Subsequently, an independent-sample t-test was used to assess sex differences in pancreatic cancer mortality, comparing urban versus rural mortality, with a cutoff of 2012, to assess the difference in mortality between 2004 and 2012 and 9 years before and after 2012–2021; The mean and 95% confidence interval (CI) were determined. Finally, the annual percentage change in mortality was calculated using an age-period-cohort model and the relative risk was estimated by cohort. This study used the national mortality statistics data from 2004 to 2021 and the literature [8] APC model method to analyze the mortality data of different age groups and different regions, and draw the APC map, to explore the trend of mortality and potential influencing factors of pancreatic cancer.

Methods and design were shown in Fig. 1.

Results

Total mortality in Chinese adults from 2004 to 2021

Mortality from 2004 to 2021 for adults over 20 years of age, 23,3676,6580 were monitored over 18 years, and 149,552 deaths from pancreatic cancer were recorded, the adjusted overall mortality rate for pancreatic cancer was 5.2(4.9–5.4), or 5200 deaths per 100,000 population. The mortality rate for pancreatic cancer in the eastern region was 6.3, with a 95% confidence interval (6.1–6.5). Pancreatic cancer mortality in the central region was 4.7 with a 95% confidence interval (4.4-5.0). Pancreatic cancer mortality in the Western region was 3.8, with a 95% confidence interval (3.4–4.1). As a result, pancreatic cancer death rates are higher in the eastern region than in the Midwest(Please refer to Table 1).

Pancreatic cancer mortality by gender, age group, and urban-rural residence, and region in China

Pancreatic cancer mortality was 6.2(5.9–6.5) in males and 4.1(3.9–4.4) in females, with a mean difference of 2.0 and 95% confidence interval (1.6–2.4). The urban mortality rate was 6.7(6.6–6.9), the rural mortality rate was 4.2(3.8–4.6), the urban mortality rate was higher than the rural mortality rate, the mean difference was 2.5, and the 95% confidence interval was 2.0-2.9. In conclusion, the mortality rate of male pancreatic cancer is significantly higher than that of female cancer, and the mortality rate

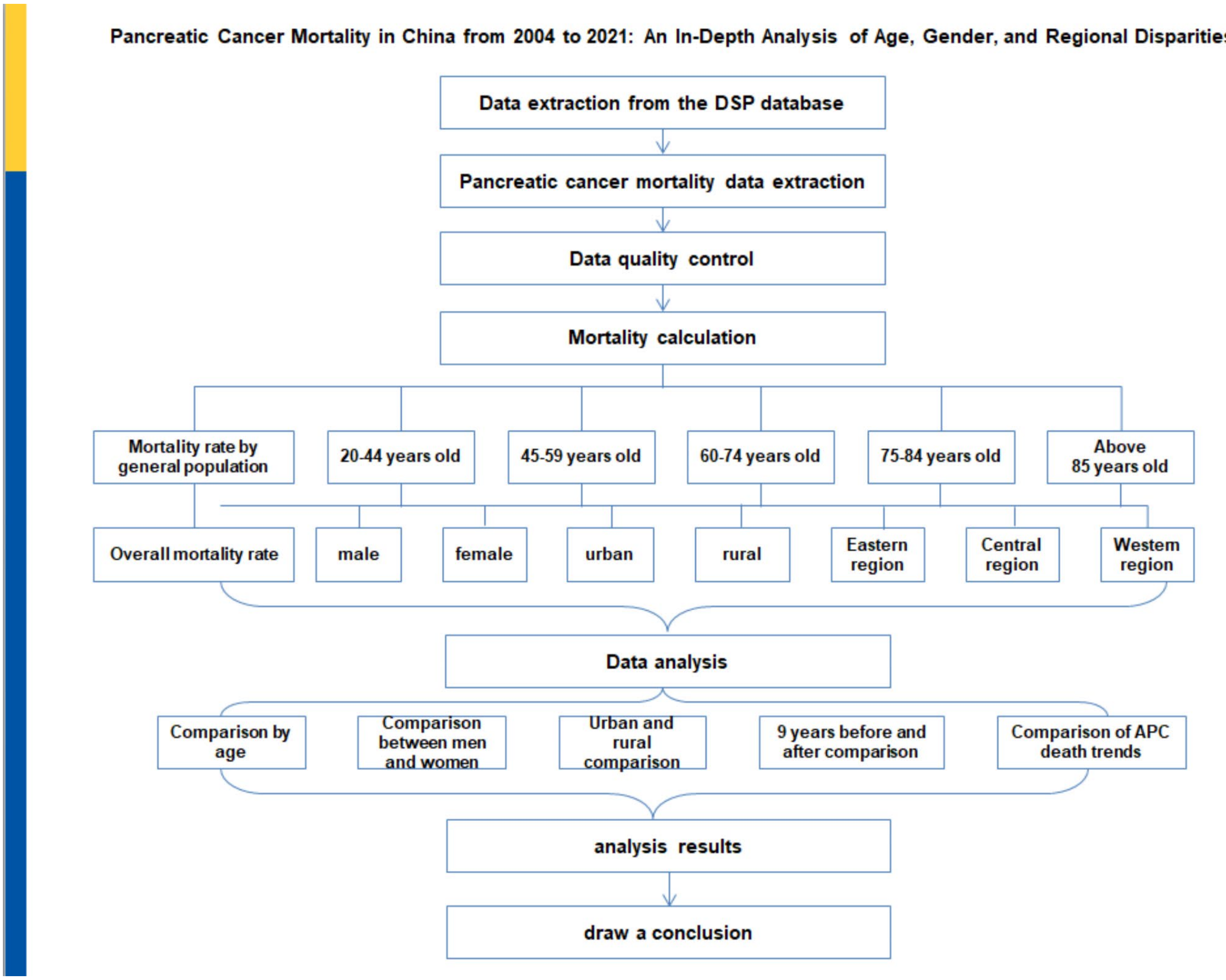

Fig. 1 Pancreatic cancer mortality in China, 2004–2021: An in-depth analysis of differences by age, sex, and region

of urban cancer is significantly higher than that of rural cancer.

The mortality rate of 117,286,4380 males and 1163,902,200 females in different age groups was monitored in the past 18 years. The mortality rate of males and females showed an increasing trend with the increase of age (see the annex for details). The mortality rate of males aged 60–74 was 11.8 (11.1–2.6). The female mortality rate was 8.1(7.6–8.5) for the same age group, with a mean difference of 3.7(2.9,4.6), the highest among all age groups, and the largest difference between men and women among all age groups. The lowest mortality rate was 0.8(0.7–0.8) for males aged 20–44 years and 0.4(0.4–0.4) for females, with a mean difference of 0.4(0.3–0.4). It can be seen that the mortality rate of the elderly aged 60–74 years old is the highest, the mortality rate of males in this age group is significantly higher than that of females, and the mortality rate of young adults aged 20–44 years old is the lowest, and the difference between males and females is the smallest.

During the monitoring period of 18 years, the urban population was 825,015,563, and the rural population was 1,511,751,017. According to the urban and rural statistics of different ages, the mortality rate of urban 60–74 years old was 12.9(12.5–13.2), and that of rural peers was 8.3(7.4–9.1). The mean difference was 4.6(3.7,5.5). The lowest mortality rate was 0.7(0.6–0.7) in the urban age group aged 20–44, 0.6(0.6–0.6) in the rural age group, and 0.1(0.0,0.2) in the mean difference. Therefore, the mortality rate of urban and rural residents aged 60–74 is the highest and the difference is the largest, and the growth rate of 20–44 is the lowest, and the difference is the smallest(Please refer to Table 2; Fig. 2).

Changes in urban and rural mortality rates over the preceding 9 years

As shown in Table 3; Fig. 3, Taking 2012 as the boundary, the change trend of pancreatic cancer mortality in 9 years before and after 2004–2007 and 2018–2021 was analyzed. Compared with the previous 9 years, the

Table 1 Total number of pancreatic cancer investigations, deaths, and age-standardized mortality rates (per 100,000 population) from 2004 to 2021, grouped by age, gender (males and females), urban and rural areas, and the Eastern, central, and Western regions

Population	Survey	Deaths	Age-adjusted mortality (95%CI)		Population	Survey	Deaths	Age-adjusted mortality (95%CI)	
Aged 20 and above	2,336,766,580	149,552	5.2	(4.9–5.4)	**Aged 60–74**	368,733,994	66,097	16.6	(15.6–17.6)
Men	1,172,864,380	86,505	6.2	(5.9–6.5)	Men	184,059,764	39,230	19.7	(18.5–21.0)
Women	1,163,902,200	63,047	4.1	(3.9–4.4)	Women	184,674,230	26,867	13.5	(12.8–14.3)
Urban	825,015,563	64,692	6.7	(6.6–6.9)	Urban	124,499,964	27,541	21.5	(20.9–22.1)
Rural	1,511,751,017	84,860	4.2	(3.8–4.6)	Rural	244,234,030	38,556	13.8	(12.4–15.3)
Eastern region	936,175,171	76,143	6.3	(6.1–6.5)	Eastern region	151,708,018	32,990	20.5	(19.5–21.5)
Central region	807,062,309	45,386	4.7	(4.4-5.0)	Central region	124,978,462	20,642	15.4	(14.4–16.3)
Western region	593,529,100	28,023	3.8	(3.4–4.1)	Western region	92,047,514	12,465	12.1	(11.0-13.2)
Aged 20–44	1,153,487,773	4,421	0.4	(0.4–0.4)	**Aged 75–84**	104,499,116	38,585	34.9	(32.9–37.0)
Men	584,995,185	2,933	0.5	(0.5–0.5)	Men	47,846,717	20,166	40.7	(38.5–42.9)
Women	568,492,588	1,488	0.3	(0.3–0.3)	Women	56,652,399	18,419	30.2	(28.2–32.2)
Urban	411,345,084	1,608	0.4	(0.4–0.5)	Urban	36,823,121	17,906	48.9	(47.7–50.0)
Rural	742,142,689	2,813	0.4	(0.3–0.4)	Rural	67,675,995	20,679	26.7	(23.5–29.8)
Eastern region	445,321,407	1,720	0.4	(0.4–0.4)	Eastern region	46,351,304	21,158	44.7	(43.0-46.3)
Central region	404,543,424	1,558	0.4	(0.4–0.4)	Central region	33,814,922	10,815	30.0	(27.6–32.4)
Western region	303,622,942	1,143	0.4	(0.4–0.4)	Western region	24,332,890	6,612	23.2	(19.9–26.5)
Aged 45–59	687,892,518	29,279	4.2	(4.0-4.4)	**Aged 85 and above**	22,153,179	11,170	47.9	(40.6–55.2)
Men	347,391,918	18,997	5.3	(5.1–5.6)	Men	8,570,796	5,179	58.8	(49.0-68.6)
Women	340,500,600	10,282	3.0	(2.9–3.2)	Women	13,582,383	5,991	41.3	(35.3–47.3)
Urban	244,690,976	11,749	5.0	(4.7–5.2)	Urban	7,656,418	5,888	77.3	(66.6–88.0)
Rural	443,201,542	17,530	3.8	(3.5-4.0)	Rural	14,496,761	5,282	30.9	(25.1–36.7)
Eastern region	282,455,074	13,445	4.8	(4.6–4.9)	Eastern region	10,339,368	6,830	63.1	(54.8–71.3)
Central region	236,781,689	9,677	4.1	(3.8–4.3)	Central region	6,943,812	2,694	39.5	(32.5–46.6)
Western region	168,655,755	6,157	3.5	(3.2–3.8)	Western region	4,869,999	1,646	28.2	(20.7–35.7)

Table 2 Mortality absolute change between urban and rural areas and between men and women in China, 2004–2021

Age	Absolute change between urban and rural areas		Absolute change between men and women	
20-	2.5	(2.0,2.9)	2.0	(1.6,2.4)
20–44	0.1	(0.0,0.2)	0.4	(0.3,0.4)
45–59	1.4	(1.0,1.9)	2.7	(2.4,3.1)
60–74	4.6	(3.7,5.5)	3.7	(2.9,4.6)
75–84	5.6	(4.7,6.4)	2.6	(1.9,3.4)
85-	4.8	(3.5,6.0)	1.8	(0.6,3.0)

mortality rate of male urban and rural men aged 60–74 increased by 0.4‰ in recent 9 years, and the confidence interval was (0.3–0.6). The mortality rate of urban men of the same age increased by 0.2‰ in recent 9 years. With a confidence interval of (0.1–0.4), the mortality rate of urban men aged 20–44 years and 75–84 years showed a downward trend in the first and second nine years. The male residents aged 20–84 in rural areas showed a significant upward trend, and the male residents aged 60–74 had the highest rate of increase, and the mortality rate increased by 0.6 (0.4–0.8) per 100,000 in recent 9 years compared with the previous 9 years. The mortality rates of men aged 60–74 years in the eastern region, men of the same age in the central region and men aged 45–84 years in the western region were on the rise. (See the attached table for details)

As shown in Table 4; Fig. 3, the death rate of women aged 60–74 in urban and rural areas increased by 0.2 per 100,000 (0.1–0.3) in the past nine years compared with the previous nine years, and the death rate of women aged 75–84 increased by 0.2 per 100,000 (0.1–0.2) in the past nine years compared with the previous nine years. The death rate of rural women aged 60–74 in the past nine years increased by 0.4 per 100,000 (0.3–0.5) compared with the previous nine years, and that of women aged 75–84 in the past nine years increased by 0.3 per 100,000 (0.2–0.4). The mortality rate of women aged 60–84 years in eastern region, women of the same age in central region and women over 60 years in western region showed an increasing trend in the past 9 years.

Therefore, the mortality rate of male pancreatic cancer at the age of 45–74 years showed an upward trend in the 9 years before and after the age of 45–74 years, in which the mortality rate of urban pancreatic cancer was on the rise at the age of 60–74 years, the mortality rate of urban pancreatic cancer was on the decline at the age of 20–44 years and 75–84 years, and the mortality rate of rural men was on the rise at the age of 20–84 years. The death

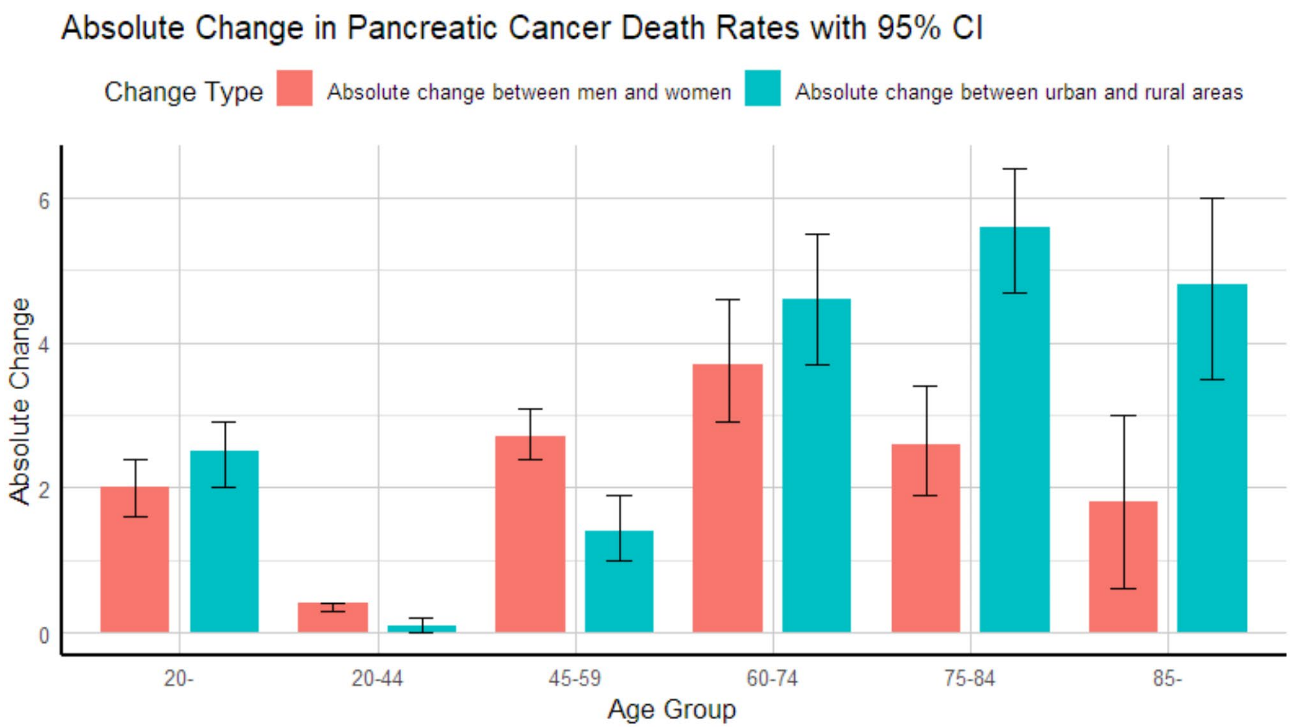

Fig. 2 Mortality absolute change between urban and rural areas and between men and women in China, 2004–2021

rate of pancreatic cancer in women aged 70–84 years was on the rise, and the death rate of rural women aged over 60 years was significantly increased. However, there was no significant difference between urban women in all age groups before and after 9 years.

Changes in APC mortality from 2004 to 2021

As shown in Fig. 4; Table 5, from 2004 to 2021, the annual growth rate of men and women was 1.6% with 95% confidence interval (1-2.2%), and the annual growth rate of women was 1% with 95% confidence interval (0.4–1.7%). The mortality rate of men with pancreatic cancer over 40 years old showed an increasing trend year by year, and the mortality rate of women with pancreatic cancer over 45 years old showed an increasing trend year by year.

The growth rate of urban men aged 35–49 showed a downward trend, among which the decline was most significant in 35–39 years, with a growth rate of -1.4%, and a 95% confidence interval of (-2.7–0.1%). For males aged 65–69, the growth rate was 0.7%, with a 95% confidence interval of (-0.1-1.2%). The mortality rate of pancreatic cancer in urban women aged 30–59 showed a decreasing trend, among which the decrease was most obvious in 30–34 years with a growth rate of -2.5%, 95% confidence interval (-4.6–0.4%), and there was no change in the other age groups.

The annual growth rate of rural males was 3.2%, with 95% confidence interval (2.5-4.0%), and the annual growth rate of over 30 was significant, among which the growth rate of over 85 was the highest 7.5%, with 95% confidence interval (2.9–12.3%), and the annual growth rate of rural females over 40 was significant. The highest annual growth rate was 7.5% for rural women over 85 years old, with a 95% confidence interval (3.9–11.1%).

There was no significant growth trend in the eastern region as a whole, but the annual growth rate of male residents over 55 in the eastern region was significant, reaching the highest of 3.04% at the age of 85, and the 95% confidence interval was (0.37–5.78%). In the eastern region, the female residents over 60 years old increased significantly year by year, reaching the highest of 2.71% at 85 years old, and the 95% confidence interval was (0.54 to 4.93%).

The central region as a whole showed an increasing trend, with a yearly growth rate of 1.89% for males and a 95% confidence interval (1.1–2.69%), a significant annual growth trend for males over 35 years old, and a yearly growth rate of 2.81% for pancreatic cancer deaths over 85 years old and a 95% confidence interval (0.93–4.74%). The growth rate of women in the central region was 1.2%, with 95% confidence interval (0.35–2.07%), and the annual growth trend of women over 45 years old was significant. The annual growth rate of pancreatic cancer death over 85 years old was 3.99%, with 95% confidence interval (1.07-7.00%).

There was no significant growth trend for males in the western region as a whole, but the annual growth rate of residents over 40 years old in the eastern region was

Table 3 The absolute change in men age-standardized pancreatic cancer mortality rates (per 100,000 population) between 2013–2021 and 2004–2012 in China

Sex	Age	Region	2013–2021 Deaths	2013–2021 IR	2004–2012 Deaths	2004–2012 IR	Absolute change	CILo	CIHi
Men	20–44	All	2239	0.2	694	0.21	0.0	0.0	0.0
Men	45–59	All	15,772	1.1	3225	0.98	0.1	0.0	0.2
Men	60–74	All	33,692	2.2	5538	1.76	0.4	0.3	0.6
Men	75–84	All	17,202	1.2	2964	1.08	0.1	0.0	0.2
Men	85-	All	4640	0.3	539	0.33	0.0	-0.1	0.1
Men	20–44	Urban	758	0.2	319	0.27	-0.1	-0.1	0.0
Men	45–59	Urban	6113	1.2	1640	1.25	0.0	-0.1	0.1
Men	60–74	Urban	13,338	2.7	2898	2.43	0.2	0.1	0.4
Men	75–84	Urban	7263	1.5	1754	1.59	-0.1	-0.2	0.0
Men	85-	Urban	2329	0.5	365	0.54	0.0	-0.2	0.1
Men	20–44	Rural	1481	0.2	375	0.18	0.0	0.0	0.1
Men	45–59	Rural	9659	1.0	1585	0.81	0.2	0.1	0.4
Men	60–74	Rural	20,354	1.9	2640	1.35	0.6	0.4	0.8
Men	75–84	Rural	9939	1.0	1210	0.75	0.3	0.2	0.4
Men	85-	Rural	2311	0.3	174	0.18	0.1	0.0	0.2
Men	20–44	Eastern region	833	0.2	273	0.22	0.0	0.0	0.0
Men	45–59	Eastern region	7212	1.2	1605	1.19	0.1	0.0	0.2
Men	60–74	Eastern region	16,821	2.7	2785	2.23	0.4	0.3	0.6
Men	75–84	Eastern region	9147	1.5	1734	1.46	0.0	-0.1	0.1
Men	85-	Eastern region	2700	0.4	328	0.42	0.0	-0.1	0.1
Men	20–44	Central region	819	0.2	236	0.20	0.0	0.0	0.1
Men	45–59	Central region	5133	1.0	1023	0.91	0.1	0.0	0.3
Men	60–74	Central region	10,361	2.0	1721	1.60	0.4	0.2	0.5
Men	75–84	Central region	4874	1.0	803	0.91	0.1	-0.1	0.3
Men	85-	Central region	1171	0.3	150	0.32	-0.1	-0.2	0.1
Men	20–44	Western region	587	0.2	185	0.20	0.0	0.0	0.1
Men	45–59	Western region	3427	1.0	597	0.75	0.2	0.1	0.4
Men	60–74	Western region	6510	1.7	1032	1.24	0.4	0.3	0.6
Men	75–84	Western region	3181	0.9	427	0.64	0.3	0.1	0.4
Men	85-	Western region	769	0.3	61	0.16	0.1	0.0	0.2

significant, and the highest rate was 5.07% between 80 and 84 years old. The 95% confidence interval was (2.71–7.48%). The overall mortality rate of female pancreatic cancer showed a significant increasing trend, and the annual growth rate of female residents over 30 years old (except 40 to 49 years old) was significant, and the annual growth rate of female pancreatic cancer death over 85 years old was 8.52%, and the 95% confidence interval was (3.39 to 13.90%).

In summary, the pancreatic cancer mortality rate of rural men over 30 years old and rural women over 40 years old increased year by year, while that of urban men aged 65–69 years old increased year by year, but the increase rate was lower than that of rural men of the same age. Urban men aged 35–39 years old and urban women aged 30–59 years old showed a negative increase year by year.

The mortality rate of female pancreatic cancer in central region and western region increased significantly year by year, while that of male pancreatic cancer in eastern region and western region did not increase significantly year by year. The death rate of pancreatic cancer in men over 55 years old in eastern region, men over 35 years old in central region and men over 40 years old in western region is increasing year by year. Pancreatic cancer mortality in women over 60 years of age in the eastern region, women over 45 years of age in the central region, and women over 30 years of age (except 40 to 49 years of age) in the Western region is increasing year by year.

Discussion

Using the National Disease Surveillance System (DSP) data from 2004 to 2021, this study systematically analyzed the changing trends and characteristics of pancreatic cancer mortality in China. A total of about 2.3 billion adults were surveyed, and the study results showed that the death rate of pancreatic cancer among Chinese adults over the age of 20 increased significantly during this period, from 1,850 deaths nationwide in 2004 to 17,618 deaths in 2021, which is about 9.5 times higher than in 2004. Overall, pancreatic cancer mortality rates

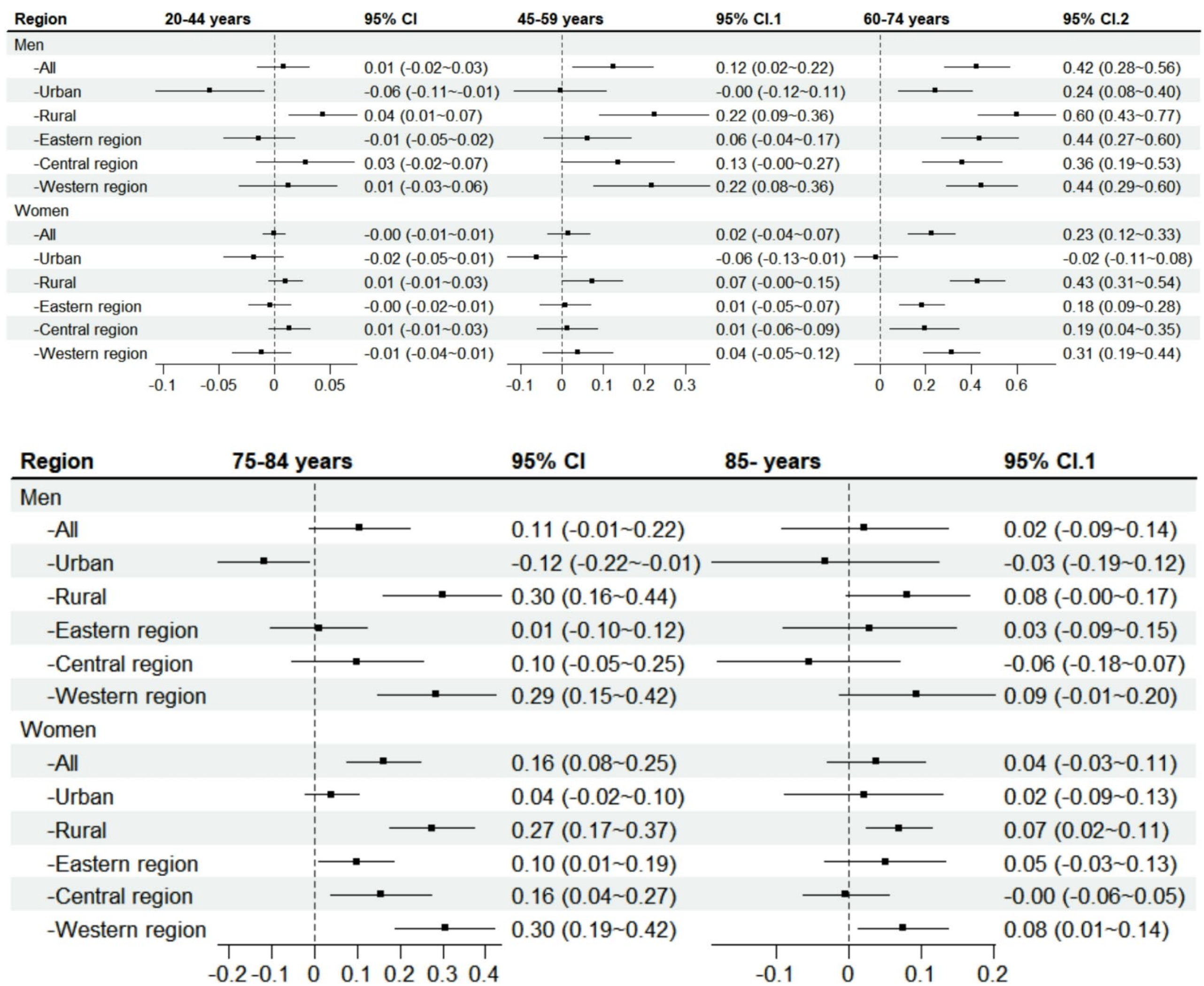

Fig. 3 The absolute change in age-standardized pancreatic cancer mortality rates (per 100,000 population) between 2013–2021 and 2004–2012 in China

increased with age, peaking in the 60–74 age group. Significant gender differences were observed, with pancreatic cancer mortality rates consistently higher in men than in women. Mortality rates were higher in urban areas compared to rural areas. However, over the past nine years, the growth rate of pancreatic cancer mortality in rural areas has been significantly faster than in urban areas. Regional analysis revealed that pancreatic cancer mortality rates were notably higher in the eastern region compared to the central and western regions, although the growth rate of mortality in the central and western regions was faster. For the first time, this study established an age-sex-urban and rural APC model for the period from 2004 to 2021, revealing a year-by-year increasing trend in pancreatic cancer mortality for both men and women. Rural areas contributed significantly to this increase, with the overall growth rate of pancreatic cancer mortality in rural men being twice that of the general male population, and the growth rate in rural women being 2.5 times that of the general female population.

The statistical analysis of this study shows that pancreatic cancer mortality among Chinese adults increased significantly between 2004 and 2021, with the number of deaths in 2021 being approximately 9.5 times that of 2004. Pancreatic cancer is the 10th most common cancer in China [3], and the incidence and mortality of pancreatic cancer have continued to rise in recent years. According to GLOBOCAN 2020, the number of new deaths of pancreatic cancer in the world is 466,003, with a mortality rate of 4.7% [2]. China accounts for about 25% of pancreatic cancer cases worldwide. Its high mortality rate is closely related to a variety of complex and diverse risk factors, such as gender, age, smoking, drinking, diabetes, obesity, chronic pancreatitis, social security, etc [9–11].

Table 4 The absolute change in women age-standardized pancreatic cancer mortality rates (per 100,000 population) between 2013–2021 and 2004–2012 in China

Sex	Age	Region	2013–2021 Deaths	2013–2021 IR	2004–2012 Deaths	2004–2012 IR	Absolute change	CILo	CIHi
Women	20–44	All	1130	0.11	358	0.11	0.00	-0.01	0.01
Women	45–59	All	8451	0.60	1831	0.59	0.02	-0.04	0.07
Women	60–74	All	22,899	1.48	3968	1.25	0.23	0.12	0.33
Women	75–84	All	15,805	0.93	2614	0.77	0.16	0.08	0.25
Women	85-	All	5378	0.25	613	0.22	0.04	-0.03	0.11
Women	20–44	Urban	384	0.11	147	0.13	-0.02	-0.05	0.01
Women	45–59	Urban	3106	0.65	890	0.71	-0.06	-0.13	0.01
Women	60–74	Urban	9084	1.78	2221	1.80	-0.02	-0.11	0.08
Women	75–84	Urban	7294	1.25	1595	1.21	0.04	-0.02	0.10
Women	85-	Urban	2780	0.40	414	0.38	0.02	-0.09	0.13
Women	20–44	Rural	746	0.11	211	0.10	0.01	-0.01	0.03
Women	45–59	Rural	5345	0.58	941	0.51	0.07	0.00	0.15
Women	60–74	Rural	13,815	1.33	1747	0.90	0.43	0.31	0.54
Women	75–84	Rural	8511	0.76	1019	0.49	0.27	0.17	0.37
Women	85-	Rural	2598	0.18	199	0.11	0.07	0.02	0.11
Women	20–44	Eastern region	465	0.12	149	0.12	0.00	-0.02	0.01
Women	45–59	Eastern region	3770	0.66	858	0.65	0.01	-0.05	0.07
Women	60–74	Eastern region	11,335	1.77	2049	1.59	0.18	0.09	0.28
Women	75–84	Eastern region	8662	1.14	1615	1.04	0.10	0.01	0.19
Women	85-	Eastern region	3389	0.34	413	0.29	0.05	-0.03	0.13
Women	20–44	Central region	394	0.11	109	0.10	0.01	-0.01	0.03
Women	45–59	Central region	2908	0.60	613	0.58	0.01	-0.06	0.09
Women	60–74	Central region	7293	1.38	1267	1.19	0.19	0.04	0.35
Women	75–84	Central region	4440	0.81	698	0.65	0.16	0.04	0.27
Women	85-	Central region	1225	0.18	148	0.18	0.00	-0.06	0.05
Women	20–44	Western region	271	0.10	100	0.11	-0.01	-0.04	0.01
Women	45–59	Western region	1773	0.52	360	0.48	0.04	-0.05	0.12
Women	60–74	Western region	4271	1.11	652	0.80	0.31	0.19	0.44
Women	75–84	Western region	2703	0.69	301	0.38	0.30	0.19	0.42
Women	85-	Western region	764	0.17	52	0.09	0.08	0.01	0.14

Age is one of the key risk factors for pancreatic cancer. This study demonstrates that pancreatic cancer mortality increases significantly with age, with the mortality rate in the 60–74 age group being markedly higher than in other age groups. This finding aligns with the results of Surveillance et al., who also emphasized the significant impact of age on pancreatic cancer mortality [12]. The 60–74 age group comprises individuals born in the mid-20th century, a generation that experienced post-war poverty, the famine during the Great Leap Forward, the social upheaval of the Cultural Revolution, and the rapid economic growth following the Reform and Opening-up period. With the progression of urbanization and industrialization, the traditional agrarian lifestyle was gradually replaced by a modern urban lifestyle. After enduring long-term resource scarcity, this generation entered a consumer society characterized by modernity, potentially leading to behaviors such as overeating, an increased preference for sweets, smoking, and alcohol consumption [13]. These behaviors may have heightened their exposure to risk factors associated with pancreatic cancer, contributing to the rise in pancreatic cancer mortality rates.

Population aging may be one of the key factors contributing to the increase in pancreatic cancer mortality. An analysis of the survey data, strictly classifying urban and rural populations based on household registration, covered individuals of all ages from birth to death, with a total of 3,032,343,064 person-years: 1,028,876,763 in urban areas and 2,003,466,302 in rural areas. The proportion of people aged 60 and above was 16.42% in urban areas and 16.29% in rural areas. However, previous literature [7] reported that pancreatic cancer mortality has been on the rise from 2005 to 2020, with higher rates in men than in women, consistent with our findings. Additionally, the report mentioned that rural areas experience a higher degree of population aging compared to urban areas due to the migration of young individuals from rural to urban regions. Contrary to this, our statistical data indicate that urban areas exhibit a higher degree of population aging than rural areas.

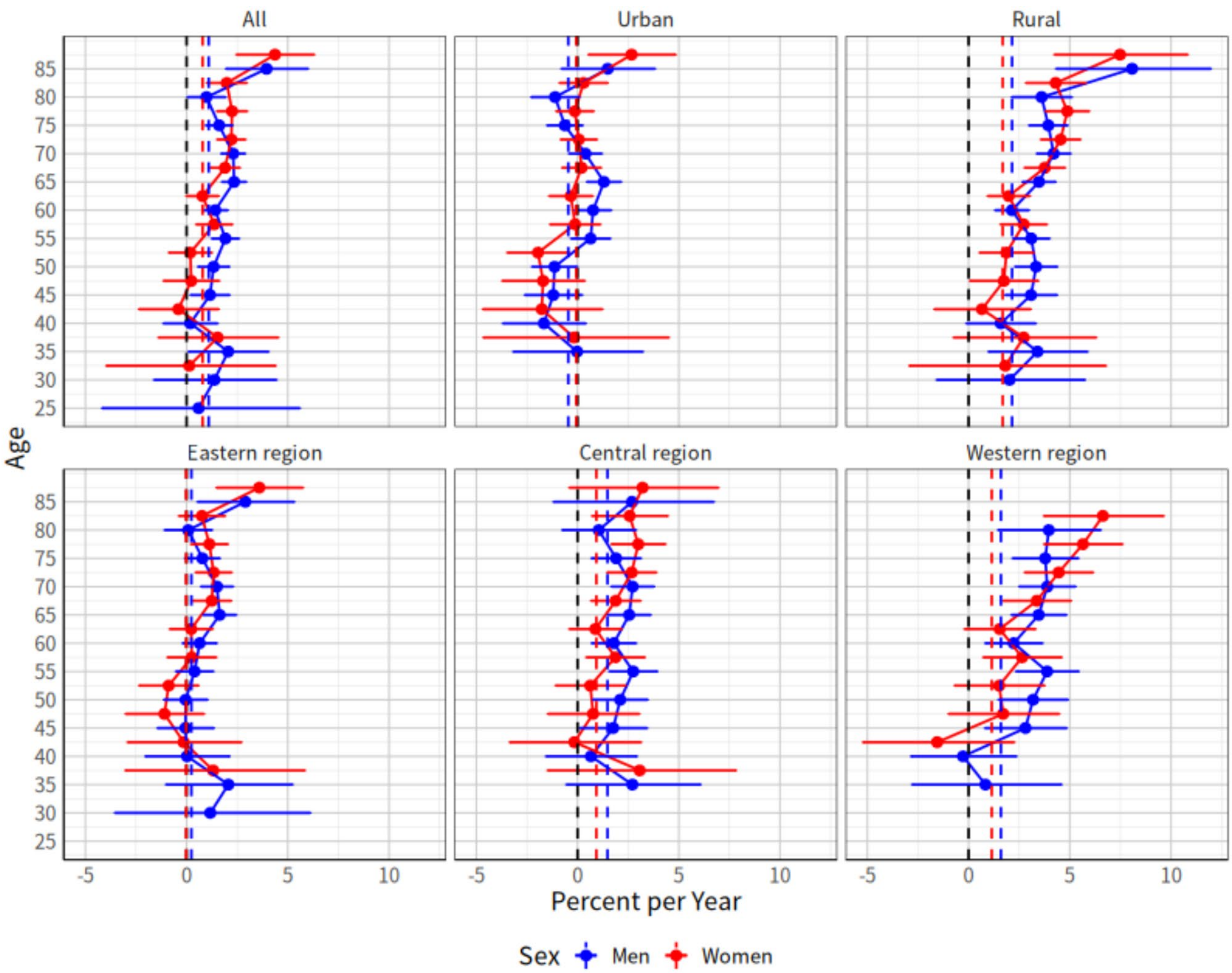

Fig. 4 Estimated annual percentage change (APC) in pancreatic cancer mortality rates grouped by sex (men and women), urban and rural areas, and the eastern, central, and western regions

China is undergoing a rapid aging process [14], with urban areas having a higher proportion of elderly populations, contributing to the higher pancreatic cancer incidence rates in urban regions [15]. This is likely linked to China's overall aging trend. According to the 7th National Census in 2021 [16], by 2020, the proportions of the population aged 60 and 65 and above were 18.7% and 13.5%, respectively, reflecting increases of 5.44% and 4.6% compared to 2010. By 2030, China's elderly population is expected to account for approximately 25% of the global total, making it the country with the largest elderly population [17]. According to research by Mizrahi et al., the incidence of pancreatic cancer in elderly populations is significantly higher than in younger populations [18].

Chronic pancreatitis is a long-term inflammatory disease of the pancreas and a risk factor for pancreatic cancer [19–21]. Persistent inflammation can lead to DNA damage and cell mutations that promote cancer. A meta-analysis [22] estimated that five years after diagnosis, patients with chronic pancreatitis had a nearly eight-fold increased risk of pancreatic cancer, a change that supports the reason why pancreatic cancer mortality has increased year by year.

Gender is an important risk factor for pancreatic cancer mortality. Our study found that males have a higher mortality rate than females, especially males aged 45 and above, whose pancreatic cancer mortality rate far exceeds that of females. Previous studies have also demonstrated that pancreatic cancer mortality is higher in males than females, consistent with our findings [3, 23]. It is well known that males possess androgens, which have immunosuppressive properties, while females have estrogens that make them more prone to autoimmune diseases. Compared to males, females generally have lower incidence and mortality rates for most cancers [24]. Men tend to have riskier lifestyles, such as smoking and drinking, which increase potential genetic susceptibility and the influence of sex steroids. These factors collectively

Table 5 Estimated annual percentage change (APC) in pancreatic cancer mortality rates grouped by sex (men and women), urban and rural areas, and the Eastern, central, and Western regions

All				**Urban**				**Rural**			
Sex	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**	
Men	20~24	\	\	Men	20~24	\	\	Men	20~24	\	\
Men	25~29	0.59	(-4.17~5.59)	Men	25~29	\	\	Men	25~29	\	\
Men	30~34	1.37	(-1.61~4.44)	Men	30~34	\	\	Men	30~34	2.02	(-1.58~5.75)
Men	35~39	2.05	(0.10~4.05)	Men	35~39	-0.03	(-3.17~3.22)	Men	35~39	3.40	(0.99~5.87)
Men	40~44	0.18	(-1.14~1.53)	Men	40~44	-1.66	(-3.69~0.41)	Men	40~44	1.59	(-0.11~3.32)
Men	45~49	1.16	(0.20~2.12)	Men	45~49	-1.20	(-2.61~0.22)	Men	45~49	3.09	(1.82~4.37)
Men	50~54	1.34	(0.57~2.11)	Men	50~54	-1.14	(-2.25~-0.02)	Men	50~54	3.34	(2.30~4.38)
Men	55~59	1.92	(1.25~2.59)	Men	55~59	0.64	(-0.32~1.62)	Men	55~59	3.10	(2.20~4.00)
Men	60~64	1.41	(0.80~2.03)	Men	60~64	0.77	(-0.12~1.66)	Men	60~64	2.14	(1.31~2.98)
Men	65~69	2.35	(1.75~2.94)	Men	65~69	1.30	(0.46~2.15)	Men	65~69	3.48	(2.67~4.30)
Men	70~74	2.30	(1.71~2.89)	Men	70~74	0.39	(-0.42~1.20)	Men	70~74	4.20	(3.38~5.03)
Men	75~79	1.61	(0.96~2.27)	Men	75~79	-0.63	(-1.50~0.25)	Men	75~79	3.94	(2.99~4.90)
Men	80~84	0.98	(0.05~1.92)	Men	80~84	-1.11	(-2.28~0.07)	Men	80~84	3.61	(2.14~5.10)
Men	85~	3.95	(1.95~5.99)	Men	85~	1.49	(-0.79~3.82)	Men	85~	8.08	(4.33~11.96)
Men	20~	1.09	(-0.69~2.91)	Men	20~	-0.46	(-3.14~2.29)	Men	20~	2.15	(0.01~4.34)
Women	20~24	\	\	Women	20~24	\	\	Women	20~24	\	\
Women	25~29	\	\	Women	25~29	\	\	Women	25~29	\	\
Women	30~34	0.13	(-3.96~4.39)	Women	30~34	\	\	Women	30~34	1.81	(-2.92~6.78)
Women	35~39	1.53	(-1.38~4.53)	Women	35~39	-0.18	(-4.65~4.50)	Women	35~39	2.72	(-0.74~6.30)
Women	40~44	-0.40	(-2.35~1.58)	Women	40~44	-1.77	(-4.68~1.22)	Women	40~44	0.66	(-1.69~3.07)
Women	45~49	0.23	(-1.14~1.61)	Women	45~49	-1.70	(-3.72~0.35)	Women	45~49	1.74	(0.07~3.44)
Women	50~54	0.18	(-0.87~1.25)	Women	50~54	-1.95	(-3.47~-0.42)	Women	50~54	1.87	(0.55~3.21)
Women	55~59	1.36	(0.48~2.26)	Women	55~59	-0.12	(-1.36~1.12)	Women	55~59	2.72	(1.58~3.87)
Women	60~64	0.79	(0.00~1.58)	Women	60~64	-0.33	(-1.40~0.75)	Women	60~64	1.98	(0.95~3.03)
Women	65~69	1.90	(1.17~2.63)	Women	65~69	0.19	(-0.76~1.16)	Women	65~69	3.76	(2.77~4.76)
Women	70~74	2.21	(1.51~2.91)	Women	70~74	0.06	(-0.83~0.96)	Women	70~74	4.54	(3.57~5.52)
Women	75~79	2.25	(1.50~2.99)	Women	75~79	-0.14	(-1.06~0.79)	Women	75~79	4.88	(3.81~5.96)
Women	80~84	1.99	(1.01~2.97)	Women	80~84	0.29	(-0.88~1.49)	Women	80~84	4.30	(2.84~5.79)
Women	85~	4.37	(2.47~6.30)	Women	85~	2.67	(0.54~4.84)	Women	85~	7.48	(4.24~10.82)
Women	20~	0.79	(-1.41~3.03)	Women	20~	-0.07	(-3.07~3.03)	Women	20~	1.69	(-0.64~4.07)

Eastern region				**Central region**				**Western region**			
Sex	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**	
Men	20~24	\	\	Men	20~24	\	\	Men	20~24	\	\
Men	25~29	\	\	Men	25~29	\	\	Men	25~29	\	\
Men	30~34	1.17	(-3.54~6.11)	Men	30~34	\	\	Men	30~34	\	\
Men	35~39	2.06	(-1.01~5.23)	Men	35~39	2.71	(-0.55~6.07)	Men	35~39	0.83	(-2.79~4.59)
Men	40~44	0.02	(-2.03~2.12)	Men	40~44	0.66	(-1.56~2.93)	Men	40~44	-0.27	(-2.84~2.36)
Men	45~49	-0.05	(-1.44~1.35)	Men	45~49	1.76	(0.11~3.44)	Men	45~49	2.81	(0.81~4.85)
Men	50~54	-0.05	(-1.12~1.04)	Men	50~54	2.11	(0.77~3.46)	Men	50~54	3.18	(1.48~4.91)
Men	55~59	0.39	(-0.52~1.32)	Men	55~59	2.75	(1.57~3.94)	Men	55~59	3.88	(2.35~5.44)
Men	60~64	0.65	(-0.20~1.49)	Men	60~64	1.79	(0.70~2.89)	Men	60~64	2.23	(0.83~3.65)
Men	65~69	1.63	(0.82~2.45)	Men	65~69	2.55	(1.50~3.61)	Men	65~69	3.47	(2.12~4.83)
Men	70~74	1.50	(0.71~2.29)	Men	70~74	2.72	(1.67~3.78)	Men	70~74	3.89	(2.51~5.28)
Men	75~79	0.78	(-0.07~1.64)	Men	75~79	1.90	(0.69~3.13)	Men	75~79	3.79	(2.18~5.43)
Men	80~84	0.08	(-1.08~1.26)	Men	80~84	1.05	(-0.76~2.88)	Men	80~84	3.96	(1.46~6.53)
Men	85~	2.90	(0.54~5.31)	Men	85~	2.70	(-1.18~6.73)	Men	85~	\	\
Men	20~	0.24	(-2.41~2.95)	Men	20~	1.48	(-1.26~4.30)	Men	20~	1.60	(-1.02~4.29)
Women	20~24	\	\	Women	20~24	\	\	Women	20~24	\	\
Women	25~29	\	\	Women	25~29	\	\	Women	25~29	\	\
Women	30~34	\	\	Women	30~34	\	\	Women	30~34	\	\
Women	35~39	1.31	(-3.02~5.84)	Women	35~39	3.07	(-1.47~7.82)	Women	35~39	\	\

Table 5 (continued)

Eastern region				Central region				Western region			
Sex	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**		**Sex**	**Age**	**Percent per Year**	
Women	40 ~ 44	-0.14	(-2.91 ~ 2.71)	Women	40 ~ 44	-0.16	(-3.35 ~ 3.14)	Women	40 ~ 44	-1.55	(-5.22 ~ 2.26)
Women	45 ~ 49	-1.09	(-3.01 ~ 0.86)	Women	45 ~ 49	0.76	(-1.47 ~ 3.05)	Women	45 ~ 49	1.71	(-0.98 ~ 4.47)
Women	50 ~ 54	-0.89	(-2.34 ~ 0.58)	Women	50 ~ 54	0.63	(-1.08 ~ 2.36)	Women	50 ~ 54	1.51	(-0.68 ~ 3.75)
Women	55 ~ 59	0.26	(-0.94 ~ 1.47)	Women	55 ~ 59	1.87	(0.43 ~ 3.32)	Women	55 ~ 59	2.64	(0.72 ~ 4.60)
Women	60 ~ 64	0.22	(-0.83 ~ 1.29)	Women	60 ~ 64	0.88	(-0.41 ~ 2.18)	Women	60 ~ 64	1.54	(-0.20 ~ 3.31)
Women	65 ~ 69	1.24	(0.29 ~ 2.20)	Women	65 ~ 69	1.88	(0.67 ~ 3.11)	Women	65 ~ 69	3.37	(1.71 ~ 5.06)
Women	70 ~ 74	1.33	(0.46 ~ 2.22)	Women	70 ~ 74	2.67	(1.47 ~ 3.89)	Women	70 ~ 74	4.45	(2.78 ~ 6.15)
Women	75 ~ 79	1.13	(0.22 ~ 2.04)	Women	75 ~ 79	3.00	(1.67 ~ 4.34)	Women	75 ~ 79	5.65	(3.73 ~ 7.60)
Women	80 ~ 84	0.75	(-0.38 ~ 1.90)	Women	80 ~ 84	2.57	(0.72 ~ 4.45)	Women	80 ~ 84	6.64	(3.72 ~ 9.63)
Women	85~	3.60	(1.49 ~ 5.75)	Women	85~	3.21	(-0.40 ~ 6.95)	Women	85~	\	\
Women	20~	-0.02	(-3.00 ~ 3.05)	Women	20~	0.93	(-2.39 ~ 4.36)	Women	20~	1.14	(-1.77 ~ 4.14)

affect metabolism, immunity, and inflammation, ultimately impacting the fidelity of genetic codes [25]. Furthermore, certain genetic mutations and family history are known risk factors for pancreatic cancer. Although genetic factors affect both males and females, some studies suggest that males may be more susceptible to certain genetic mutations. For instance, among carriers of BRCA2 mutations, males exhibit a higher incidence of pancreatic cancer [26]. Additionally, survey data from 2013 to 2018 [19] indicate that the prevalence of diabetes in males is higher than in females, which may partly explain the higher pancreatic cancer mortality rate in males.

Smoking and drinking are positively correlated with the occurrence of pancreatic cancer [27]. China is the world's largest producer and consumer of cigarettes [28]. There is a gender difference in smoking. In China, the smoking rate of men is significantly higher than that of women [29], about 49.7% of men and 3.5% of women have a smoking habit [30]. In clinical practice, smoking accelerates the development of chronic pancreatitis and induces pancreatic cancer [31]. Carcinogens in cigarettes, such as polycyclic aromatic hydrocarbons and nitrosamines, can directly induce genetic mutations in pancreatic cells, activate oncogenes and inhibit oncosuppressor genes [32]. Bogumil D et al. [27] found that the risk of pancreatic cancer in smokers was significantly higher than that of non-smokers, and the risk of pancreatic cancer in smokers gradually decreased with the extension of quitting smoking time, and quitting smoking at any time could help reduce the risk of pancreatic cancer. This sex difference may explain part of the higher death rate from pancreatic cancer in men. Alcohol consumption is also a risk factor for pancreatic cancer, and the rate of alcohol consumption in Chinese men and women is 55.6% and 15% [33]. There is a significant association between alcohol consumption and pancreatic cancer [34], especially in long-term heavy drinkers [35]. The sex difference in alcohol consumption also explains one reason for the higher death rate from pancreatic cancer in men. Both smoking and excessive alcohol consumption significantly increase the risk of pancreatic cancer [36].

Pancreatic cancer mortality shows regional differences. Our study indicates that the pancreatic cancer mortality rate in urban areas is higher than in rural areas; however, the growth rate in rural areas is faster than in urban areas. Residents registered as rural or urban households in a particular location have their health insurance, education, pensions, and other social security benefits determined by their household registration location [37]. Rural elderly individuals receive fewer social benefits, such as pensions and medical insurance, compared to urban elderly individuals [38]. The social security system in rural areas is weaker than in urban areas, and socioeconomic status is negatively correlated with the incidence of pancreatic cancer [39]. Those with lower socioeconomic status tend to detect pancreatic cancer later, have lower chances of surgical resection, and worse postoperative outcomes [40]. This may be related to lower healthcare expenditures in rural areas, higher out-of-pocket costs, and a heavier economic burden [41], which leads to a lack of personal health awareness and a lack of regular physical check-ups in rural areas, contributing to the increasing pancreatic cancer mortality rate in rural areas year by year.

Diabetes is also one of the important risk factors for pancreatic cancer. In recent years, the prevalence of diabetes has increased [42], and the risk of pancreatic cancer in diabetic patients has increased significantly. The association between diabetes and pancreatic cancer may be realized through various mechanisms, including insulin resistance, hyperglycemic environment, changes in insulin-like growth factor (IGF) levels, and chronic inflammation of pancreatic tissue [43]. According to 2013 statistics, 43.1% of adults in urban areas had diabetes compared to 29.1% in rural areas, which may be the reason for more pancreatic cancer patients in urban areas.

For the first time, this paper divides China into eastern region, central region and western region according to the criteria of economic development level, geographical location, national policy orientation and other criteria (political economy method) combined with China's national conditions. We compare the mortality rate of pancreatic cancer in the three regions, and the results show that the total mortality rate of pancreatic cancer in the eastern region is higher than that in the central and western region. This is roughly the same as the results of previous studies [44]. However, this paper analyzes the continuity of pancreatic cancer mortality data over the past 18 years, and the annual growth rate of pancreatic cancer mortality of residents in the central and western regions is higher than that in the eastern region. According to literature reports, the mortality rate of pancreatic cancer is related to the urbanization rate, which is 37.2% in western region, 53.3% in eastern region, and 45.3% in central region [45]. The eastern region is highly urbanized, with higher total energy intake, higher fat intake, especially trans fatty acids [46], which makes it more likely to increase the prevalence of overweight and obesity compared to the central and western regions. Overweight and obesity are risk factors for diabetes [47], so the prevalence and mortality rate of diabetes in the eastern region are higher than in the central and western regions [48–50]. Based on the pancreatic cancer mortality statistics in this study, regions with higher urbanization rates have more diabetes patients, which may lead to higher pancreatic cancer mortality rates. However, the socioeconomic development in the central and western regions lags behind that in the eastern region, and the social medical insurance enjoyed in these areas is lower than in the eastern region [38], which may result in later detection or treatment of pancreatic cancer, lower chances of surgical resection, and worse postoperative outcomes. Additionally, healthcare spending in rural areas is lower, the out-of-pocket ratio is higher, and the economic burden is heavier. Rural residents lack personal health awareness and regular check-ups. Furthermore, the smoking rate in the western region is higher than in the eastern region [28, 51], and the level of green development in the eastern region (including resource utilization, pollution control, living environment, ecological protection, circular economy, and quality of economic growth) is higher than that in the western region [52]. These factors may also contribute to the faster increase in pancreatic cancer mortality rates in the western region compared to the eastern region.

Future studies should continue to explore the combined effects of urbanization, economic development level, obesity, diet, environmental pollution, and hepatobiliary diseases on the incidence of pancreatic cancer in order to develop more effective prevention and care interventions. In addition, studies should consider the interaction of gender, age, and environmental factors to fully understand how these factors influence pancreatic cancer morbidity and mortality. Conducting early screening and regular health check-ups for high-risk populations in high-risk regions, especially before symptoms appear, and developing personalized prevention and treatment strategies will help reduce the burden of pancreatic cancer.

Limitation

This study utilized data from the DSP system to analyze trends in pancreatic cancer mortality in China. While this dataset offers nationwide coverage and long-term surveillance, it does have some limitations. First, the accuracy of the data relies on the quality of local reporting, which may lead to under-reporting or incomplete information. When evaluating the DSP system's ability to capture the diversity of China's population, it is evident that although the system aims to reflect national trends by establishing surveillance points across the country, there are certain limitations in its comprehensive representation of population diversity in remote areas. The current DSP system may not fully account for the complexity of China's geographical environment and the significant regional disparities. The uneven distribution of surveillance points also affects the representativeness and general applicability of the data. To enhance the effectiveness and accuracy of the DSP system, future research needs to focus more on optimizing the distribution of surveillance points. Second, the lack of individual-level data on key risk factors such as smoking and diabetes may introduce confounding bias. Additionally, differences in the quality of diagnosis and treatment across regions were not fully accounted for, which may affect the generalizability of the results. Future research should aim to incorporate more detailed individual data and consider a broader range of factors to enhance the reliability and applicability of the findings.

Conclusion

This study analyzed pancreatic cancer mortality in China from 2004 to 2021, revealing a significant increase in mortality over the 18-year period. The death rates were higher among males, urban residents, and in the eastern regions, with the highest mortality observed in low-aged elderly males aged 60 to 74. However, the increases in rural, central regions and western regions were also notable. This trend is closely related to changes in lifestyle and regional economic factors, including aging, diabetes, smoking, alcohol consumption, and chronic pancreatitis. Additionally, political and economic factors may also influence mortality rates. Therefore, public health interventions targeting lifestyle and socioeconomic factors will be a key focus for reducing pancreatic cancer mortality in the future.

Author contributions
Rui He and Qiuping Chen contributed equally to this work, providing significant input in study design, data analysis, and manuscript preparation. Zhengnan Shen, Haiyang Hu, and Xin Ding were involved in data collection and interpretation, as well as the revision of the manuscript for critical intellectual content. Zhenglong Zheng and Quansheng Feng, both of whom are corresponding authors, supervised the study and ensured its integrity. Baixue Li played a key role in conceptualizing the research and coordinating the overall project. All authors approved the final version of the manuscript for submission.

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Data availability
The mortality statistics of pancreatic cancer across the country from 2004 to 2021 in this article can be obtained from "China Mortality Monitoring Data Set (2021)", which was published by Science and Technology Press of China. It was compiled by the Chronic Non-communicable Disease Prevention and Control Center of the Chinese Center for Disease Control and Prevention and the Statistical Information Center of the National Health Commission. The download address is: https://ncncd.chinacdc.cn/jcysj/siyinjcx/syfxbg/202403/W020230317353700905354.pdf.

Declarations

Ethics approval and consent to participate
This study was carried out strictly in accordance with the Declaration of Helsinki. The Ethics committee of Chengdu University of Traditional Chinese Medicine approved our study and agreed to waive informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Cai J, Chen H, Lu M, et al. Advances in the epidemiology of pancreatic cancer: trends, risk factors, screening, and prognosis[J]. Cancer Lett. 2021;520:1–11.
2. Huang J, Lok V, Ngai CH, et al. Worldwide burden of, risk factors for, and trends in pancreatic cancer[J]. Gastroenterology. 2021;160(3):744–54.
3. Han B, Zheng R, Zeng H, et al. Cancer incidence and mortality in China, 2022. J Natl Cancer Cent. 2024;4(1):47–53.
4. Vincent A, Herman J, Schulick R, et al. Pancreatic cancer[J]. Lancet. 2011;378(9791):607–20.
5. Halbrook CJ, Lyssiotis CA, di Magliano MP, et al. Pancreatic cancer: advances and challenges[J]. Cell. 2023;186(8):1729–54.
6. Zhu B, et al. Epidemiological characteristics of pancreatic cancer in China from 1990 to 2019. Cancer Control. 2021;28:10732748211051536.
7. Xu Y, et al. Mortality and years of life lost due to pancreatic cancer in China, its provinces, urban and rural areas from 2005 to 2020: results from the National mortality surveillance system. BMC Cancer. 2023;23(1):893.
8. Shiels MS, Chernyavskiy P, Anderson WF, et al. Trends in premature mortality in the USA by sex, race, and ethnicity from 1999 to 2014: an analysis of death certificate data[J]. Lancet. 2017;389(10073):1043–54.
9. Hu JX, Zhao CF, Chen WB, Liu QC, Li QW, Lin YY, Gao F. Pancreatic cancer: A review of epidemiology, trend, and risk factors. World J Gastroenterol. 2021;27(27):4298–321.
10. Rawla P, Sunkara T, Gaduputi V. Epidemiology of pancreatic cancer: global trends, etiology and risk factors. World J Oncol. 2019;10(1):10–27. https://doi.org/10.14740/wjon1166. Epub 2019 Feb 26. PMID: 30834048; PMCID: PMC6396775.
11. Zanini S, Renzi S, Limongi AR, et al. A review of lifestyle and environment risk factors for pancreatic cancer[J]. Eur J Cancer. 2021;145:53–70.
12. Surveillance. Epidemiology, and end results program. cancer.stat facts: pancreatic cancer. [cited 20 Jan 2021]. In: National Cancer Institute. https://seer.cancer.gov/statfacts/html/pancreas.html.
13. Román Ruiz G. Echoes of famine: effects of the embodied memories of the Spanish hunger years (1939–1952) on survivors' subsequent food practices and attitudes. Memory Studi. 2023;17(4):692–708.
14. Tu WJ, Zeng X, Liu Q. Aging tsunami coming: the main finding from China's seventh National population census[J]. Aging Clin Exp Res. 2022;34(5):1159–63.
15. Luo Y, Su B, Zheng X. Trends and challenges for population and health during population aging—China, 2015–2050[J]. Volume 3. China CDC weekly; 2021. p. 593. 28.
16. The Population Division of the Department of Economic and Social Affairs of United Nations Secretariat. World Population Prospects: The 2019 revision, 2019.
17. Zhu H, Walker A. Population ageing and social policies in China: challenges and opportunities[J]. Routledge Handb Chin Stud. 2021:191–204. eBook ISBN: 9780429059704.
18. Mizrahi JD, Surana R, Valle JW, et al. Pancreatic cancer[J]. Lancet. 2020;395(10242):2008–20.
19. Wang L, Peng W, Zhao Z, et al. Prevalence and treatment of diabetes in China, 2013–2018[J]. JAMA. 2021;326(24):2498–506.
20. Vujasinovic M, Dugic A, Maisonneuve P, et al. Risk of developing pancreatic cancer in patients with chronic pancreatitis[J]. J Clin Med. 2020;9(11):3720.
21. Gandhi S, De La Fuente J, Murad MH, et al. Chronic pancreatitis is a risk factor for pancreatic cancer, and incidence increases with duration of disease: a systematic review and meta-analysis[J]. Clin Translational Gastroenterol. 2022;13(3):e00463.
22. Kirkegård J, Mortensen FV, Cronin-Fenton D. Chronic pancreatitis and pancreatic cancer risk: a systematic review and meta-analysis[J]. Official J Am Coll Gastroenterology| ACG. 2017;112(9):1366–72.
23. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries[J]. Cancer J Clin. 2024;74(3):229–63.
24. Ben-Batalla I, Vargas-Delgado ME, Von Amsberg G, et al. Influence of androgens on immunity to self and foreign: effects on immunity and cancer[J]. Front Immunol. 2020;11:1184.
25. Haupt S, Caramia F, Klein SL, et al. Sex disparities matter in cancer development and therapy[J]. Nat Rev Cancer. 2021;21(6):393–407.
26. Cheng HH, Shevach JW, Castro E et al. BRCA1, BRCA2, and associated Cancer risks and management for male patients: A review[J]. JAMA Oncol. 2024;10(9):1272–1281.
27. Bogumil D, Stram D, Preston DL, et al. Excess pancreatic cancer risk due to smoking and modifying effect of quitting smoking: the multiethnic cohort Study[J]. Cancer Causes Control. 2024;35(3):541–8.
28. Zhang G, Zhan J, Fu H. Trends in smoking prevalence and intensity between 2010 and 2018: implications for tobacco control in China[J]. Int J Environ Res Public Health. 2022;19(2):670.
29. Xiao L, Nan Y, Di XB et al. Study on smoking behavior and its changes among Chinese people aged 15 years and above in 2018[J]. Zhonghua Liu Xing Bing Xue Za Zhi, 2022, 43(6): 811–7.
30. Amram DL, Zagà V, Serafini A, et al. Tobacco smoking and gender differences: epidemiological aspects[J]. Tabaccologia. 2023;21(1):27–35.
31. Malfertheiner P, Schütte K. Smoking—a trigger for chronic inflammation and cancer development in the pancreas[J]. Official J Am Coll Gastroenterology| ACG. 2006;101(1):160–2.
32. Duell EJ. Epidemiology and potential mechanisms of tobacco smoking and heavy alcohol consumption in pancreatic cancer[J]. Mol Carcinog. 2012;51(1):40–52.
33. Li Y, Jiang Y, Zhang M, et al. Drinking behaviour among men and women in China: the 2007 China chronic disease and risk factor Surveillance[J]. Addiction. 2011;106(11):1946–56.
34. Rumgay H, Murphy N, Ferrari P, et al. Alcohol and cancer: epidemiology and biological mechanisms[J]. Nutrients. 2021;13(9):3173.
35. Bagnardi V, Rota M, Botteri E, Tramacere I, Islami F, Fedirko V, Scotti L, Jenab M, Turati F, Pasquali E, et al. Alcohol consumption and site-specific cancer risk: A comprehensive dose–response meta-analysis. Br J Cancer. 2014;112:580.

36. Shaji PD, Martinez Bulnes A, Diego VP et al. Unraveling the mechanisms by which smoking and alcohol alter pancreatic Cancer Pathogenesis[J]. 2023.
37. Bairoliya N, Miller R. Social insurance, demographics, and rural-urban migration in China[J]. Volume 91. Regional Science and Urban Economics; 2021. p. 103615.
38. Cheng Y, Gao S, Li S, et al. Understanding the Spatial disparities and vulnerability of population aging in China[J]. Asia Pac Policy Stud. 2019;6(1):73–89.
39. Pang Y, Kartsonaki C, Guo Y, et al. Socioeconomic status in relation to risks of major Gastrointestinal cancers in Chinese adults: a prospective study of 0.5 million people[J]. Cancer Epidemiol Biomarkers Prev. 2020;29(4):823–31.
40. Abdel-Rahman O. Impact of socioeconomic status on presentation, treatment and outcomes of patients with pancreatic cancer[J]. J Comp Eff Res. 2020;9(17):1233–41.
41. Ying M, Wang S, Bai C, et al. Rural-urban differences in health outcomes, healthcare use, and expenditures among older adults under universal health insurance in China[J]. PLoS ONE. 2020;15(10):e0240194.
42. Yuan C, Babic A, Khalaf N, et al. Diabetes, weight change, and pancreatic cancer risk[J]. JAMA Oncol. 2020;6(10):e202948–202948.
43. Li D. Diabetes and pancreatic cancer[J]. Mol Carcinog. 2012;51(1):64–74.
44. Zhao C, Gao F, Li Q, et al. The distributional characteristic and growing trend of pancreatic cancer in China[J]. Pancreas. 2019;48(3):309–14.
45. Maimaitiming A, Xiaolei Z, Huhua C. Urbanization in Western China[J]. Chin J Popul Resour Environ. 2013;11(1):79–86.
46. Jiang L, Shen J, Zhao Y, et al. Trans fatty acid intake among Chinese population: a longitudinal study from 1991 to 2011[J]. Lipids Health Dis. 2020;19:1–9.
47. Xu X, Byles JE, Shi Z, et al. Evaluation of older Chinese People's macronutrient intake status: results from the China health and nutrition Survey[J]. Br J Nutr. 2015;113(1):159–71.
48. Wang F, Wang W, Yin P, et al. Mortality and years of life lost in diabetes mellitus and its subcategories in China and its provinces, 2005–2020[J]. J Diabetes Res. 2022;2022(1):1609267.
49. Zhou M, Astell-Burt T, Yin P, et al. Spatiotemporal variation in diabetes mortality in China: multilevel evidence from 2006 and 2012[J]. BMC Public Health. 2015;15:1–10.
50. Zuo H, Shi Z, Hussain A. Prevalence, trends and risk factors for the diabetes epidemic in China: a systematic review and meta-analysis[J]. Diabetes Res Clin Pract. 2014;104(1):63–72.
51. Liu YN, Liu JM, Liu SW et al. Death and impact of life expectancy attributable to smoking in China, 2013[J]. Zhonghua Liu Xing Bing Xue Za Zhi, 2017, 38(8): 1005–10.
52. Yang W, Hu Y, Ding Q, et al. Comprehensive evaluation and comparative analysis of the green development level of provinces in Eastern and Western China[J]. Sustainability. 2023;15(5):3965.

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