

RESEARCH ARTICLE



Subnational trend and driving factors for pancreatic cancer burden in China, 1990–2021: an analysis based on the Global Burden of Disease Study 2021

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ABSTRACT

Background: The mortality of pancreatic cancer in China showed an increasing trend between 2005 and 2020, with significant discrepancies in the burden of pancreatic cancer in provinces.

Methods: We analyzed numbers of death, incidence, disability-adjusted life years (DALY) and corresponding age-standardized rates for pancreatic cancer in China using data from the Global Burden of Disease Study 2021. We conducted trend analysis in pancreatic cancer burden over time by age group and gender. Decomposition analysis was used to assess the drivers of change in cancer-related deaths in China due to three explanatory factors: population growth, population ageing and age-specific mortality.

Results: In 2021, the ASMR of pancreatic cancer in China was 5.72/100,000(95%UI: 4.59, 6.91), the age-standardized incidence (ASIR) rate was 5.64/100,000(95%UI: 4.52, 6.84) and the age-standardized DALY rate was 137.23/100,000 (95%UI:108.15, 166.74). From 1990 to 2021, the ASMR of pancreatic cancer in China generally showed an increasing trend (AAPC: 0.56, 95%UI: 0.52, 0.59). The burden of pancreatic cancer was consistently higher in Chinese men compared to women during the study period. Compared with 1990, the number of deaths from pancreatic cancer has increased in all provinces of China in 2021, with the overall number of deaths increasing by 67.49%. Population ageing was the major cause of the increase in deaths from pancreatic cancer in China, accounting for 45.89%.

Conclusions: The burden of pancreatic cancer in China is still at a high level and population ageing is the main reason for the increase in pancreatic cancer deaths.

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Introduction

Pancreatic cancer is a highly aggressive and lethal malignant tumour [1,2]. GLOBAL CANCER statistics showed that pancreatic cancer ranked as the 7th leading cause of all malignant tumour deaths worldwide in 2020 [3]. The annual number of incident cases of pancreatic cancer in 2017 has more than doubled globally in comparison with 25 years ago [2,4]. Both the prevalence and incidence of pancreatic cancer showed an increasing trend between 2009 and 2018 in some developed countries in North America and Europe [5]. In China, an emerging developing country with rapid economic growth, the trend of pancreatic

cancer mortality has been consistent with that of high HDI countries. It ranked as the 6th leading cause of cancer death in China in 2020 [6], and the trend of incidence and mortality are both increasing [7]. In the context of decline for overall cancer mortality and mortality for most of the cancer types, pancreatic cancer has become a major public health issue in Chinese population.

Previous studies from high-income countries indicated that there were substantial geographic variations for incidence rate and mortality rate of pancreatic cancer across countries and regions, possibly due to different lifestyles, inherited risk factors and environmental

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factors [5]. One recent study in China also showed significant provincial differences in age-standardized mortality rates (ASMR) and age-standardized years of life lost (YLL) rates for pancreatic cancer from 2005 to 2020 [8]. In the rapidly ageing Chinese population with unbalanced economic development in different regions, comprehensive and timely analyses of the trend and geographic variations of burden of pancreatic cancer can provide important evidence for policy makers. In addition, drivers of the increasing trend of pancreatic cancer are also important but remained unclear in China.

Based on the latest Global Burden of Disease Study 2021 (GBD 2021) China subnational data, this study aims to: 1) analyze the current status and trends of pancreatic cancer incidence, mortality and disability-adjusted of life years (DALY) in China and its provinces during 1990–2021; and 2) explore the driving factors for the observed growth of the burden caused by pancreatic cancer in both national and subnational level in China.

Methods

Overview

GBD 2021 is a systematic analysis of the burden of disease worldwide [9,10], aiming to provide comprehensive estimates of multiple burden of disease indicators for 288 causes of death and 371 diseases and injuries for 204 countries and territories from 1990 to 2021 [11,12]. It provides in-depth analyses of the disease burden by gender, age and location worldwide. Detailed information on the GBD 2021 study can be found from the Global Health Data Exchange (GHDx) GBD 2021 website [13]. The current study focused on the burden of pancreatic cancer, including estimates for mortality, incidence and DALY in 33 provincial-level administrative regions (including 22 provinces, five autonomous regions, four municipalities and two special administrative regions, hereafter referred to as 'provinces') in China from 1990 to 2021. Pancreatic cancer is coded 157 in the 9th edition of the International Classification of Diseases (ICD9) and C25.0–C25.9 in the 10th edition (ICD-10).

Data sources

The data used for estimates of pancreatic cancer deaths in China were obtained from the China Disease Surveillance Points System, the China Center for Disease Control and Prevention death reporting system, the

China Cancer Registry System, the vital registration system for Hong Kong and Macao, and so on [10,14,15]. Data sources for non-fatal outcomes in pancreatic cancer are based on systematic reviews of Chinese and world scientific publications [13]. These datasets above have been detailed in previous studies [16,17]. Socio-Demographic Index (SDI) data were obtained from the GBD 2021. The SDI is a composite measure that combines the rescaled total fertility rates among women younger than 25 years, the years of educational attainment in the population older than 15 years, and the lag-distributed income per person [18,19].

Measures

Detailed descriptions of the GBD estimation process were published in the GBD capstone papers [11,20,21]. Briefly, a cause-of-death modelling tool developed by GBD was used for estimates of death burden, and the DisMod-MR 2.1 was used for the estimates of the incidence for non-fatal outcomes. DALYs for pancreatic cancer are the total number of healthy life years lost from incidence to death, including both life years lost due to premature death and healthy life years lost due to disability.

Statistical analysis

In this study, we analyzed the numbers of death, incidence, DALY and corresponding age-standardized rates for pancreatic cancer in China and 33 provinces. We compared the differences in indicators in 1990 and 2021 as well as the percentage change during the study period between China and the global average. We conducted trend analysis in pancreatic cancer burden over time by age group and gender. To investigate gender disparities in pancreatic cancer burden across China and its provincial divisions, we conducted a comparative analysis of male-to-female sex ratios for ASMR, ASIR and age-standardized DALY rates in 2021.

We analyzed the age-standardized DALY rates for pancreatic cancer in different provinces and compared their percentage changes from 1990 to 2021. Joinpoint model was used to calculate the average annual percentage change (AAPC) in ASMR for pancreatic cancer in China and 33 provinces from 1990 to 2021 to understand the national and subnational trend of the burden due to pancreatic cancer in China over time. $p < 0.05$ indicates a statistically significant trend. To illustrate the provincial level variations of the secular trend, we mapped the rankings of ASMR for pancreatic cancer by province in China from 1990 to 2021.

To understand the drivers of changes of deaths due to pancreatic cancer in China, this study analyzed the decomposition of changes using a method developed by Gupta [6,22,23]. The method attributes change in the number of pancreatic cancer deaths in China to three factors: population growth, population ageing and age-specific mortality in China [24]. Specifically, this study calculates the number of deaths under two scenarios based on counterfactual theory. Under scenario 1, to measure the extent to which population growth contributes to the number of deaths. It is assumed that the total national and provincial population in 2021 is the actual level, while the national and subnational population structure and age-specific mortality rates in 2021 remain the same as those in 1990. The expected number of pancreatic cancer deaths in 2021 for the national and subnational populations can be derived by calculating the total population in 2021 and the demographic and age-specific mortality rates in 1990. Under Scenario 2, to measure the extent to which population growth and population ageing contribute to the number of deaths. It is assumed that the total national and subnational population in 2021 will be at the actual level. The national and provincial age-specific mortality rates in 2021 are calculated from the total population and the population structure in 2021, and the age-specific mortality rates in 1990. Therefore, the extent to which population growth contributes to changes in the total number of deaths is obtained from the difference between the estimated number of deaths in Scenario 1, 2021, and the actual number of deaths in 1990. The extent to which population ageing contributes to changes in total deaths is obtained from the difference between the Scenario 2 results and the Scenario 1 results. The extent to which changes in age-specific mortality rates contribute to changes in total deaths is obtained from the difference between the actual number of deaths in 2021 and Scenario 2. We employed locally weighted regression to examine the association between China's SDI and pancreatic cancer burden metrics, including ASMR, ASIR and age-standardized DALY rate.

The data were statistically analyzed using Excel 2019, SAS 9.4, Joinpoint 5.0.2.0, R4.3.1, ArcMap10.8 and Visio2021 were utilized to plot the relevant results. Point estimates and 95% uncertainty intervals for each indicator are given in this study.

Ethical approval

This study strictly followed the ethical principles of the Declaration of Helsinki. The secondary data analysis was performed by using the publicly available and

de-identified data without involving human subjects. Therefore, the ethics committee of the National Center for Chronic and Non-communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, determined that the institutional review board approval for this study was waived, and informed consent was not required.

Results

Burden of pancreatic cancer in China and worldwide, 1990 and 2021

In 2021, the number of pancreatic cancer incidence in China constituted 23.33% of the total global incidence, and the number of deaths accounted for 23.65% of global pancreatic cancer deaths. The ASMR of pancreatic cancer in China was 5.72/100,000 (95%UI: 4.59, 6.91), and the age-standardized incidence (ASIR) rate was 5.64/100 000 (95%UI: 4.52, 6.84), which were lower than the global average (ASMR (95%UI):5.95/100 000 (5.40, 6.41), ASIR (95%UI): 5.96/100,000 (5.39, 6.42)).

In 2021, the number of DALYs of pancreatic cancer was 2,930.32 thousand (95%UI: 2,301.05, 3,575.08) in China, accounting for 25.89% of the global DALY for pancreatic cancer. The age-standardized DALY rate was 137.23/100,000 (95%UI:108.15, 166.74), higher than the global average [130.33/100,000 (95%UI: 120.52, 140.13)]. In 2021, the number of pancreatic cancer deaths, ASMR, incidence, ASIR, DALY and age-standardized DALY rates in China increased by 207.59%, 18.36%, 213.78%, 24.18%, 161.55% and 11.42%, respectively, compared to 1990 (Table 1).

Trends in the burden for pancreatic cancer, 1990–2021

The overall burden caused by pancreatic cancer showed an increasing trend in China from 1990 to 2021 (Figure 1). There was a significant upward trend for the ASMR, ASIR and age-standardized DALY rate of pancreatic cancer for Chinese men from 1990 to 2021, while these rates for women were in a relatively stable state. During the study period, the burden of pancreatic cancer in Chinese men was consistently higher than that in women.

Burden of pancreatic cancer by gender and age in China

In 2021, the number of pancreatic cancer incidences, deaths and DALYs in China was much higher in older

Table 1. Burden of pancreatic cancer in China and worldwide, 1990 and 2021.

Measure	Globe				China			
	1990		2021		1990		2021	
	Percent change (%)		Percent change (%)		Percent change (%)		Percent change (%)	
Deaths	211.61 (199.99, 221.95)	505.75 (461.22, 543.90)	139.00 (119.12, 158.19)	38.88 (32.79, 45.26)	119.60 (95.65, 145.22)	207.59 (122.27, 310.14)	119.60 (95.65, 145.22)	207.59 (122.27, 310.14)
ASMR (/100,000)	5.66 (5.33, 5.93)	5.95 (5.40, 6.41)	5.18 (-3.28, 13.07)	4.83 (4.10, 5.61)	5.72 (4.59, 6.91)	18.36 (-13.52, 56.49)	5.72 (4.59, 6.91)	18.36 (-13.52, 56.49)
Incidence	207.91 (196.65, 217.78)	508.53 (462.09, 547.21)	144.60 (124.31, 164.12)	37.82 (31.79, 44.07)	118.67 (94.62, 144.66)	213.78 (126.59, 318.71)	118.67 (94.62, 144.66)	213.78 (126.59, 318.71)
ASIR (/100,000)	5.47 (5.16, 5.73)	5.96 (5.39, 6.42)	8.93 (0.28, 17.08)	4.54 (3.84, 5.29)	5.64 (4.52, 6.84)	24.18 (-9.78, 64.66)	5.64 (4.52, 6.84)	24.18 (-9.78, 64.66)
DALYs	5,210.48 (4,967.40, 5,481.66)	11,316.96 (10,464.70, 12,169.34)	117.20 (96.75, 136.80)	1,120.35 (941.08, 13,065.09)	2,930.32 (2,301.05, 3,575.08)	161.55 (86.91, 252.34)	2,930.32 (2,301.05, 3,575.08)	161.55 (86.91, 252.34)
Age-standardized DALY rate (/100,000)	129.32 (122.98, 135.98)	130.33 (120.52, 140.13)	0.78 (-8.49, 9.59)	123.16 (103.69, 143.27)	137.23 (108.15, 166.74)	11.42 (-20.12, 49.29)	137.23 (108.15, 166.74)	11.42 (-20.12, 49.29)

Note. Number of deaths, morbidity, DALY in thousands. ASMR is age-standardized mortality rate. ASIR is age-standardized incidence rate.

age group (> 50 years) than in younger age group (< 50 years). The number of pancreatic cancer deaths (Men: 72,159 (95%UI: 54,384, 92,255), Women: 47,443 (95%UI: 35,778, 60,492), incidence (Men: 72,280 (95%UI: 54,334, 92,975), Women: 46,386 (95%UI: 34,923, 59,339)) and DALYs (Men: 1,854,033 (95%UI: 1,382,248, 2,393,909), Women: 1,076,284 (95%UI: 806,636, 1,392,992)) were higher in men than in women. In 2021, the ASMR, ASIR and age-standardized DALY rates of pancreatic cancer in China increased with age for both genders. There were higher ASMR (Men: 7.37/100,000 (95%UI: 5.64, 9.30), Women: 4.29/100,000 (95%UI: 3.23, 5.46), ASIR (Men: 7.29/100,000 (95%UI: 5.55, 9.24), Women: 4.18/100,000 (95%UI: 3.15, 5.34)) and age-standardized DALY rates (Men: 179.36/100,000 (95%UI: 134.98, 229.10), Women: 96.89/100,000 (95%UI: 72.70, 125.18)) of pancreatic cancer in men than in women in all age groups (Figure 2).

In 2021, the sex ratios (males to females) for pancreatic cancer in China were 1.72 for ASMR, 1.74 for ASIR and 1.85 for age-standardized DALY rate. The analysis revealed sex ratios exceeding 1 at both national and subnational levels, indicating a significantly elevated pancreatic cancer burden among males compared to females across China. Spatial distribution patterns of these gender disparities are presented in Appendix Figures S1, S2 and S3 through provincial-level maps. Notably, our study identified distinct geographical variations in gender disparities, with southern Chinese provinces exhibiting systematically higher sex ratios compared to their northern counterparts. Guangxi Province, in particular, has one of the highest pancreatic cancer burden sex ratios in the country (with ASMR of 2.55, ASIR of 2.60 and age-standardized DALY rate of 2.82).

Geographic variations in different provinces of China in 1990 and 2021

Substantial geographical variations were observed for age-standardized DALYs rate for pancreatic cancer across China in 2021 (Figure 3). The provinces with highest age-standardized DALY rates for pancreatic cancer in China in 2021 were Shanghai (273.55/100,000, 95%UI: 197.88, 373.21), Liaoning (231.89/100,000, 95%UI: 176.47, 304.66), Heilongjiang (230.32/100,000, 95%UI: 173.09, 305.77) and Zhejiang (227.30/100,000, the 95%UI: 162.67, 312.89). Provinces in China with the lowest age-standardized DALY rates were Macao (74.46/100,000, 95%UI: 47.66, 108.31), Guangxi (75.86/100,000, 95%UI: 54.16, 100.86), Hunan (80.99/100,000, 95%UI: 59.62, 104.06)

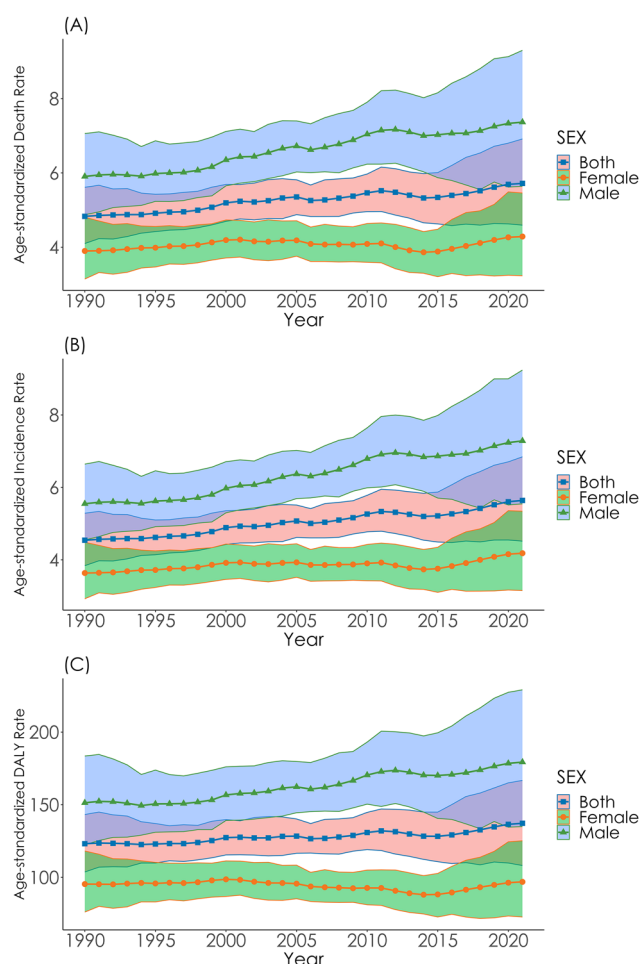


Figure 1. Trends in ASMR, ASIR and age-standardized DALY rates of pancreatic cancer in China, 1990–2021.

and Hainan (85.40/100,000, 95%UI: 62.10, 118.13), all in southern regions. The burden of pancreatic cancer was generally higher in the eastern provinces than in the western provinces, and generally higher in the northern provinces than in the southern provinces. The percentage change during 1990–2021 in age-standardized DALY rates for pancreatic cancer was highest in the provinces of Hebei (46.75%), Liaoning (40.68%) and Henan (37.71%). In 2021, there were 11 provinces in China with age-standardized DALY rates for pancreatic cancer that were lower than those in 1990, with the largest decrease in Macao (-29.1%) and Jiangxi (-22.51%).

From 1990 to 2021, the ASMR of pancreatic cancer in China generally showed an increasing trend (AAPC: 0.56, 95%UI: 0.52, 0.59). From 1990 to 2021, 10 provinces showed a faster increasing trend of ASMR for pancreatic cancer than the national average in (Figure S4). Among all provinces in China, ASMR for pancreatic cancer were increasing in 25 province and decreasing in six provinces. Only Heilongjiang and

Anhui did not have a statistically significant AAPC on the ASMR of pancreatic cancer ($p > 0.05$). Shanghai ranked first in the ASMR of pancreatic cancer in 1990 and 2021, and the ASMR of pancreatic cancer in Shanghai showed an increasing trend during this period (AAPC: 0.46(0.39, 0.56)). Among the other provinces, Liaoning rose to third place from ninth place, and Sichuan to 14th place from 23rd place (Figure S4).

The results of the locally weighted regression analysis revealed that an SDI value of approximately 0.75 marked the inflection point for the decline in pancreatic cancer burden in China (Figure 4). Below this threshold ($SDI < 0.75$), the age-standardized DALY rate for pancreatic cancer showed a positive association with SDI, whereas above this threshold ($SDI > 0.75$), the rate demonstrated a negative association with increasing SDI (Figure 4). This nonlinear pattern was consistently observed in separate analyses examining the relationships between SDI and both age-standardized mortality rate (ASMR) and age-standardized incidence rate (ASIR) of pancreatic cancer (Figures S5, S6).

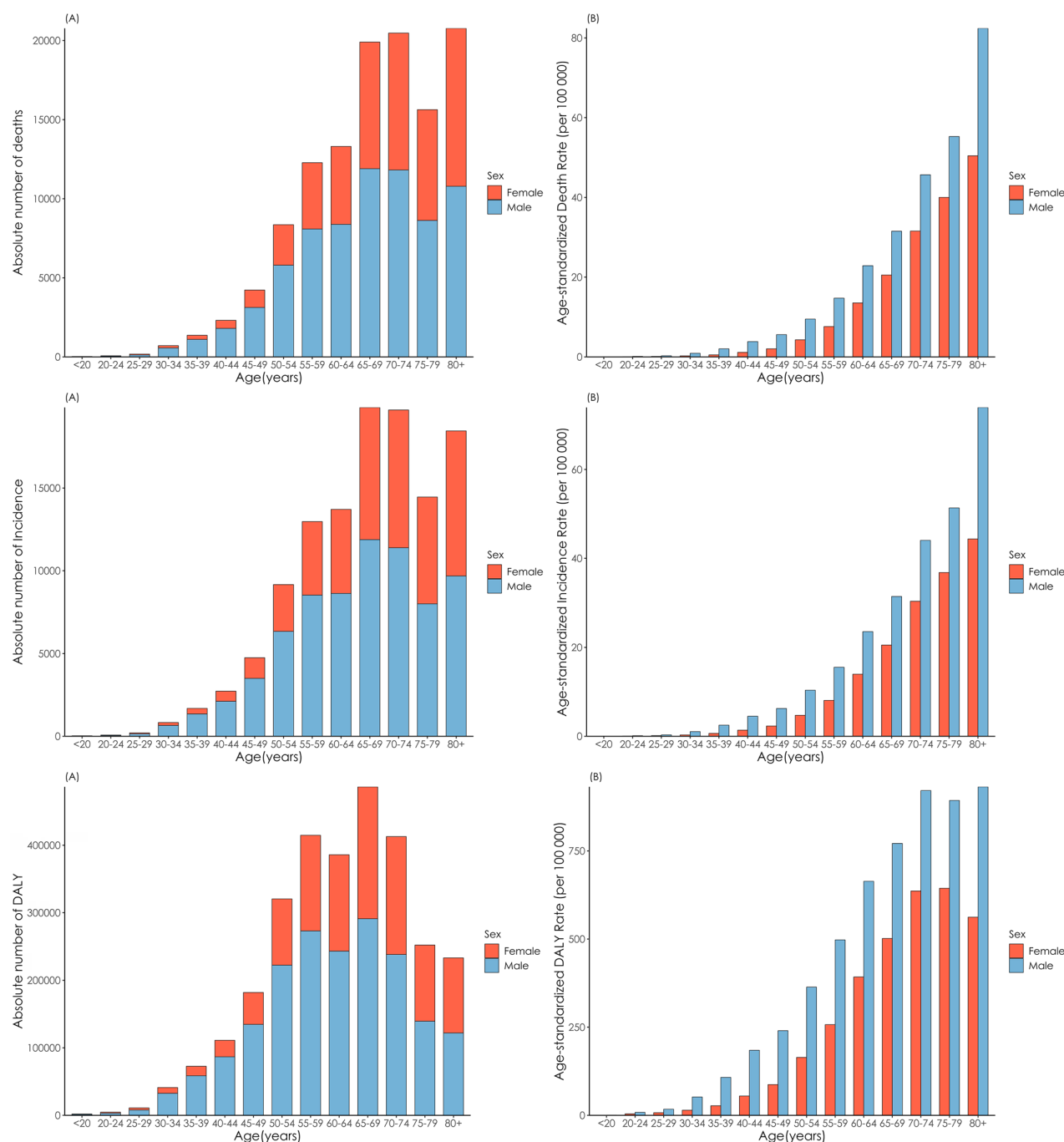


Figure 2. Number of pancreatic cancer deaths, incidence, DALYs (A) and mortality, incidence rates, DALY rates (B) by age and sex in China, 2021.

Decomposition of changes of pancreatic cancer deaths in different provinces of China during 1990–2021

Compared with 1990, the number of deaths due to pancreatic cancer has increased in all provinces of China in 2021, with the overall number of deaths increasing by 67.49% (Figure 5). Almost all provinces increased more than 50% in the number of deaths due to pancreatic cancer, except for Tibet (48.69%). Population ageing was the major cause of the increase

in deaths from pancreatic cancer in China, accounting for 45.89%. Change due to age-specific mortality rate and change due to population growth were secondary drivers of the absolute increase in pancreatic cancer deaths in China, jointly explaining 21.61% of the total death count growth (14.80% and 6.81%, respectively). The provinces with the highest percentage increase in the number of deaths from pancreatic cancer were Chongqing (80.19%), Ningxia (76.57%), Tianjin (75.14%) and Hebei (73.59%). In the vast majority of provinces,

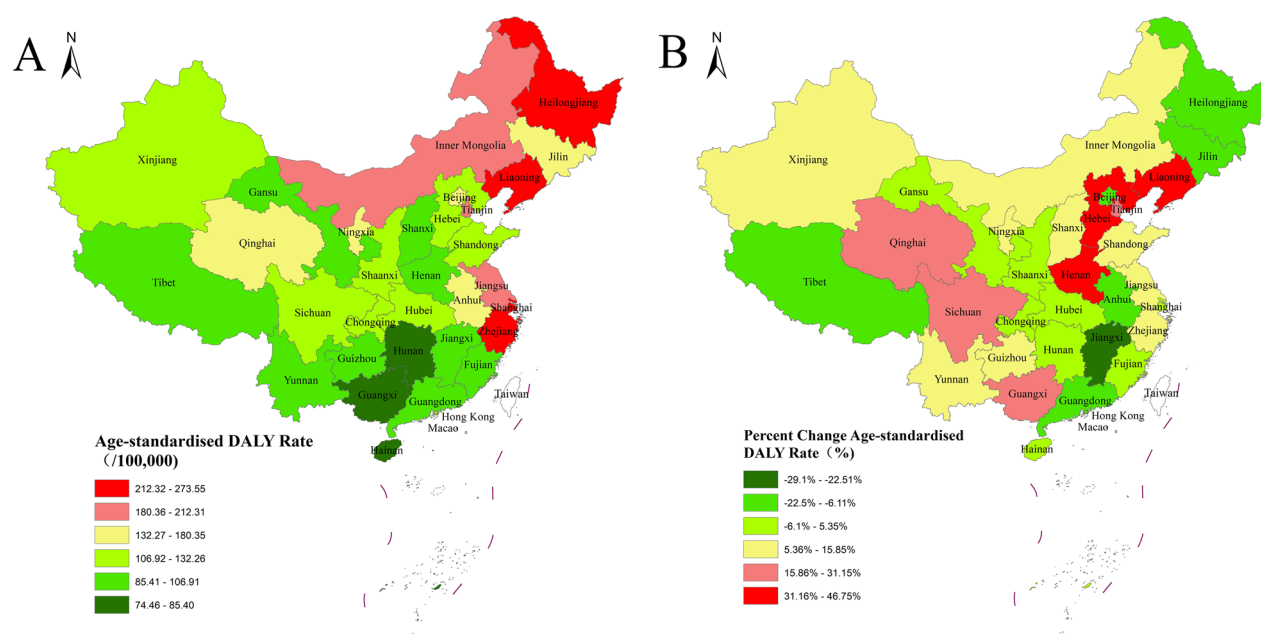


Figure 3. Chinese provincial age-standardized DALY rates for pancreatic cancer in 2021 and percentage change in Chinese provincial age-standardized DALY rates for pancreatic cancer, 1990–2021.

ageing was the main reason for the increase in the number of pancreatic cancer deaths, except in Tibet, where the main reasons for the increase in the number of pancreatic cancer deaths were population growth and population ageing, contributing 33.26% and 30.53%, respectively. Among all provinces, the province with the highest contribution of population ageing to the increase in pancreatic cancer deaths was Jilin Province (70.84%).

Discussion

In this study, we observed that the burden of pancreatic cancer in China increased from 1990 to 2021. The DALY burden of pancreatic cancer in China was higher than the global average, and there were large differences between provinces. The ranking of ASMR of pancreatic cancer changed considerably in different provinces during the study period, and increased in provinces with a more ageing population, such as Sichuan. Population ageing was the main reason for the increase in the burden of pancreatic cancer in China.

The burden of pancreatic cancer was consistently higher in Chinese men than in women during 1990–2021. This may be related to the gender differences in biological and psychological factors [2]. Firstly, a higher proportion of Chinese men than women have unhealthy lifestyles, such as smoking [25,26,] and alcohol consumption [27,28,], which are risk factors for pancreatic cancer. The results of five consecutive

nationally representative cross-sectional surveys in China show that smoking prevalence among Chinese men declined from 58.4% in 2007 to 50.8% in 2018, while among Chinese women, it remained stable at around 2% [29]. Secondly, the roles played by men and women in the family are different, and men generally face higher life pressure. Long-term mental stress may lead to decreased immunity, which in turn increases the risk of the disease.

The burden of pancreatic cancer and the trend of change varies greatly among different provinces. The variations in economic development, lifestyle, distribution of medical resources, etc may explain the reasons [2,30,31]. During the study period, economically developed eastern regions such as Shanghai and Zhejiang had the highest ASMR for pancreatic cancer, which is in line with previous findings from studies in Australia, Europe and North American states [32,33]. The burden of pancreatic cancer in the northern provinces of China was generally higher than in the southern regions, which may be related to the difference in dietary structure. Because of the cold winters in the northern regions, the diet structure in the north was more inclined to high-fat, high-protein and high-calorie foods. This dietary pattern was strongly associated with diabetes, which is a significant risk factor for pancreatic cancer [34]. There are differences in climate, soil, water quality and other natural conditions in different provinces, which may have an impact on the physical condition of residents [31]. The distribution of medical resources and the level of diagnosis and

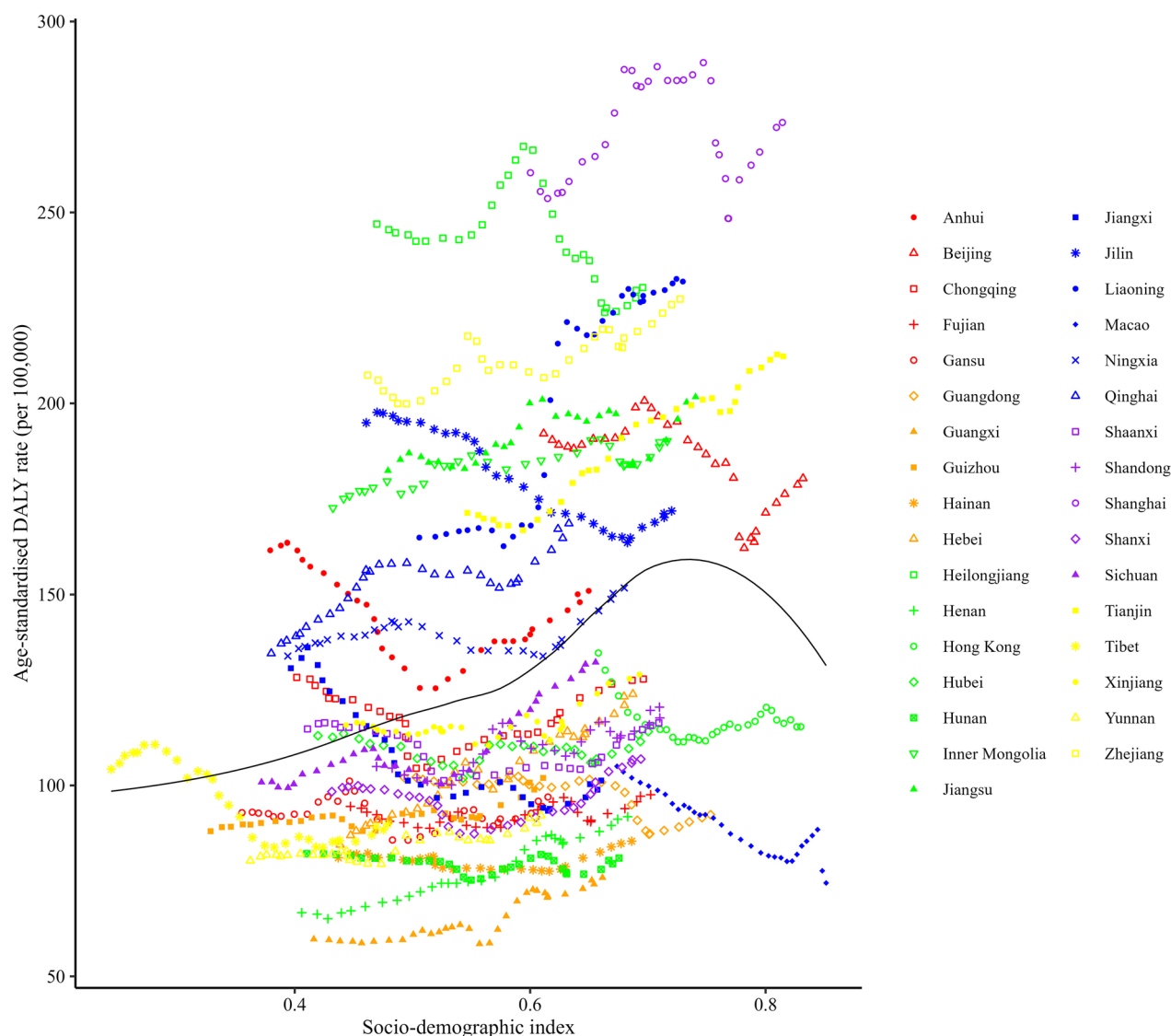


Figure 4. Age-standardized DALY rate for pancreatic cancer by SDI in subnational regions of China from 1990 to 2019.

treatment have an impact on the prevention and control of pancreatic cancer [35].

Meanwhile, we found that the level of SDI in different provinces can, to some extent, explain the variations in pancreatic cancer burden across these regions. Specifically, our analysis revealed an inverse association between SDI and pancreatic cancer burden in high-SDI regions ($SDI > 0.75$), whereas distinct patterns emerged in low-SDI regions ($SDI < 0.75$). These findings align with previous Global Burden of Disease (GBD) 2019 research encompassing 29 cancer types, which demonstrated divergent temporal trends in ASMRs across SDI quintiles: increases in low and low-middle SDI quintiles (2010–2019) contrasted with declines in middle-high quintiles [36]. Similarly, ASIRs exhibited increases in low-to-middle SDI quintiles but decreases in middle-high and high SDI quintiles, with the most pronounced reductions observed in high-SDI regions [36].

Existing evidence suggests that elevated cancer burden in low-SDI regions may be closely associated with ageing, enhanced cancer surveillance capabilities, and differential exposure to risk factors, particularly smoking pattern variations across SDI gradients [37,38]. Conversely, high-SDI regions benefit from substantial public health investments that facilitate advanced screening and early intervention strategies. These systemic advantages prove particularly critical for malignancies with poor prognoses such as pancreatic cancer, where timely detection significantly impacts clinical outcomes [39].

Our study found that population ageing was the main reason for the increase in the number of pancreatic cancer deaths during the study period, which is also consistent with previous studies [8]. We speculate that discrepancies in the degree of population ageing in different provinces may also contribute to regional

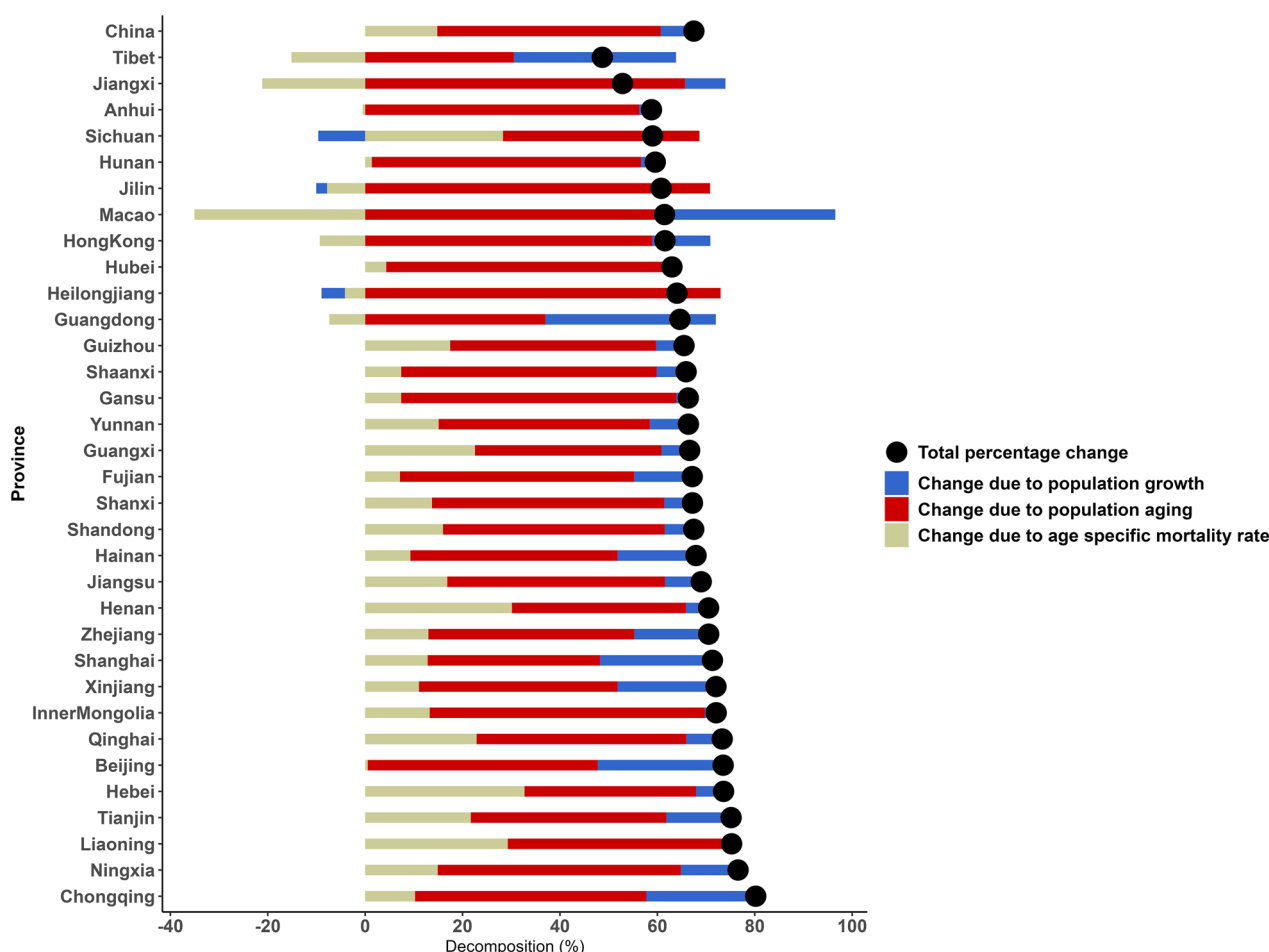


Figure 5. Decomposition of changes in pancreatic cancer deaths due to population growth, population ageing and age-specific mortality rate in China and 31 provinces, 1990–2021.

differences in pancreatic cancer burden, for example, Sichuan, Liaoning and Hebei provinces are relatively more ageing, and they all have a greater elevation in ASMR rankings for pancreatic cancer. In the context of China's ageing population, we predict that the burden of pancreatic cancer may further increase, especially in provinces with a severely ageing population. Meanwhile, we observed that during the study period, some provinces had relatively lower ASMR for pancreatic cancer, but the rate of increase was higher than the national average, and the ranking of ASMR went up, for example, Henan and Guizhou. Attention should also be given to these provinces as the burden might be concealed by the low mortality rate caused by pancreatic cancer.

The results found that the burden of pancreatic cancer was high among the elderly and that early screening and treatment was the main way to reduce the burden of pancreatic cancer, but due to unremarkable early symptoms of pancreatic cancer, it is difficult to carry out large-scale early screening. Therefore, we suggest that medical and health institutions should

strengthen health education for the elderly and popularize knowledge about pancreatic cancer, such as the incidence of pancreatic cancer, risk factors, prevention methods and so on. Secondly, the elderly should be encouraged to live a healthier lifestyle.

The main strengths of this study lie in the following aspects. First, the data collection, processing, and analyzing methods of GBD 2021 have been subjected to strict quality control and validation, and the results of GBD 2021 have been widely used as evidence to inform policy. Second, this study spans a long period and demonstrates the secular trend of burden caused by pancreatic cancer in both national and provincial level in China. Third, we conducted a decomposition analysis to explore the main driving factors for the increase in the number of pancreatic cancer deaths in different provinces during the study period, which provides data support for regional pancreatic cancer prevention and control policies in China.

This study also has some limitations. Firstly, this study is based on data analyzed from GBD 2021, so all the general limitations of GBD 2021 apply to this

study. Secondly, previous studies have shown that the burden of pancreatic cancer is different in urban and rural areas due to imbalances in healthcare resources, population ageing gaps and disparities in health awareness of the population [8]. Because GBD 2021 does not have data on the burden of disease by urban-rural dimension, we were unable to explore the urban-rural disparity. However, we analyzed the discrepancy between different provinces in detail, which to a certain extent can explain the difference in pancreatic cancer burden in areas with unequal healthcare resources. Thirdly, due to data availability, we could not comprehensively address unmeasured confounding factors, including evolving diagnostic methodologies, individual-level environmental exposures, survival-related confounders and other residual variables. Concurrently, while decomposition models offer a theoretical framework for analyzing mortality determinants, we cannot systematically evaluate all risk factor distributions associated with pancreatic cancer across China and therefore cannot provide direct evidence for tailored intervention. Nevertheless, through standardized longitudinal analysis of Global Burden of Disease (GBD) data, we robustly demonstrated that the ageing population constitutes a high-risk demographic cohort for pancreatic cancer mortality. Further studies on attributable risk factors in different provinces in China are needed.

In conclusion, the burden of pancreatic cancer in China is still at a high level, and it varies greatly among different provinces. More precise and tailored preventive and control measures in different provinces are needed to effectively reduce the burden of pancreatic cancer, which is likely to continue to rise in the context of ageing.

Acknowledgments

Maigeng Zhou and Peng Yin designed the study. Fanshu Yan drafted the manuscript. Fanshu Yan, Lingling Yu, Zhe Liu, Jinlei Qi and Lijun Wang participated data analysis and interpretation. All authors have read and approved the final version of the manuscript.

Author contributions

CRedit: **Fanshu Yan**: Data curation, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing; **Lingling Yu**: Formal analysis, Validation; **Zhe Liu**: Formal analysis, Validation; **Jinlei Qi**: Formal analysis, Supervision; **Lijun Wang**: Formal analysis, Supervision; **Maigeng Zhou**: Conceptualization, Supervision; **Peng Yin**: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data from NMSS and study materials will be made available to other researchers from the corresponding author on reasonable request for purposes of reproducing the results or replicating the procedure.

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