The top 5 causes of death in China from 2000 to 2017
Haiyin Zou1,2, Zheng Li1, Xinjie Tian3 & Yongcheng Ren1,2*

Limited information is available on the epidemiological characteristics of major causes of death in the last 18 years. In this study, we investigated the epidemiological characteristics of the top 5 causes of death in China from 2000 to 2017. Data were obtained from the 18-year reports of Ministry of Health and analyzed by Grid Search Method, Permutation test, and log-linear regression model. The top 5 consistent causes of death, malignant tumor, cerebrovascular disease, heart trouble, respiratory disease, trauma and toxicosis accounted for 82.6% in 2000, 86.49% in 2017 in urban areas and 83.31% in 2000, 88.34% in 2017 in rural areas. The increasing trends (P < 0.05) of proportions of death of malignant tumor, cerebrovascular disease, and heart trouble have average annual percent change (AAPC) = 0.5%, 0.3%, 2.4% in urban areas and 1.7%, 1.5%, 4.3% in rural areas. The AAPCs of respiratory disease are −1.4% in urban areas and −3.6% in rural areas. Cardio-cerebrovascular disease increased (Urban: 39.02% to 43.56%, AAPC = 1.3%, P < 0.05; Rural: 32.03% to 45.91%, AAPC = 2.7%, P < 0.05) steeply from 2000 to 2017 which are higher than that of malignant tumor (P < 0.05). The top 5 causes of death in China accounted for more than 85% of all deaths in 2017, in which cardio-cerebrovascular disease accounted for the largest proportion with the steepest increasing trend.

One of the most important ways to assess the effectiveness of a country's health system is to measure the number of deaths and their causes each year. It is also important to understand the way how diseases and injuries affect people. Health authorities could use the statistics data of different causes of death during different periods as an effective tool to establish their focus in public health area which may help both to extend the lifespan and to improve the life quality of their people.

The noncommunicable diseases caused by aging and health transitions have brought huge burden to the developing countries, increasing the most economically productive age span rapidly in those countries. Therefore, to developing countries, adult mortality rate becomes an important indicator for a comprehensive assessment of the mortality pattern in the population. It is critical to improve the quality of cause-of-death data to improve the health conditions and reduce preventable deaths in population of the developing countries. In 1987, Ministry of Health of China established a vital registration system to record the incidence and causes of death. Until 2005, this system had covered 41 urban sites and 85 rural sites with population from 30,000–70,000. From 2006 to the present, the cause-of-death monitoring system which includes 161 monitoring sites, has been carried out on the National Disease Surveillance System.

From 2000 to 2017, there was an acceleration of urbanization and an economic boom in China. Risk factors for death have shifting patterns, and population health have fundamental transformations. However, few studies in China have revealed these transition trends, leaving the relations between population health and the development of society poorly characterized. Such information is crucial for population health professionals and policymakers to determine the next step in public health work and political reform in China. Our study analyzed the nationally representative data provided by the Ministry of Health and explored the epidemiological characteristics and secular trends of the top 5 causes of death in China from 2000 to 2017, with a close examination of demographic and ecological changes, trying to find the focus of intervention to reduce the risk of death.

Methods
Study design and sample. In this study, data of the proportion and causes of death were obtained from the China Statistical Yearbooks (2001–2018), which have been provided by the Ministry of Health and published by national bureau of statistics of China annually since 2001. The original sample was collected by using multistage stratified and cluster probability proportional sampling methods, which consists of participants from the general population of China with the provincial units as a secondary population, but excludes the popula-
Results
The top 5 consistent causes of death are malignant tumor, cerebrovascular disease, heart trouble, respiratory disease, and trauma and toxicosis, of the period from 2000 to 2017. These 5 diseases account for 82.6% in 2000, 86.49% in 2017 in urban areas and 83.31% in 2000, 88.34% in 2017 in rural areas of the total deaths, respectively. The corresponding data were 83.99%, 87.15%, 83.40%, and 88.93% in males and 80.90%, 85.59%, 81.63%, and 86.49% in 2017 in urban areas and 83.31% in 2000, 88.34% in 2017 in rural areas of the total deaths, respectively.

Table 1. The trends of the top 5 causes of death in urban areas of China from 2000 to 2017. APC Annual Percent Change; AAPP Average Annual Percent Change; CI confidence interval. Significant values are in bold. *Indicates that AAPC or APC is significantly different from zero at the alpha = 0.05 level.

| Gender | Diseases            | Trends (1)        | Trends (2)        |
|--------|---------------------|-------------------|-------------------|
|        | Year-range          | APC (95% CI, %)   | Year-range        | APC (95% CI, %)   | AAPP (95% CI, %) |
| Male   | Malignant Tumor     | 2000–2007 1.8 (0.2–3.4)* | 2007–2017 −0.5 (−1.4–0.4) | 0.4 (−0.1–0.9) |
|        | Cerebrovascular Disease | 2000–2002 −8.4 (−21.7–7.2) | 2002–2017 0.8 (0.1–1.5) | 0.3 (−0.3–1.0) |
|        | Heart Trouble       | 2000–2002 −7.1 (−25.2–15.3) | 2002–2017 2.7 (1.8–3.6)* | 2.2 (1.4–3.0)* |
|        | Respiratory Disease | 2000–2010 −1.9 (−3.7–−0.1)* | 2010–2017 0.1 (−3.0–3.3) | −1.1 (−1.9–0.4)* |
| Female | Trauma and Toxicosis| 2000–2017 −0.5 (−1.7–0.7) | − | −0.5 (−1.7–0.7) |
|        | Malignant Tumor     | 2000–2017 0.7 (0.1–1.3)* | − | 0.7 (0.1–1.3)* |
|        | Cerebrovascular Disease | 2000–2002 −5.7 (−17–7.2) | 2002–2017 0.8 (0.2–1.3)* | 0.4 (0.1–0.9) |
|        | Heart Trouble       | 2000–2002 −6.7 (−28.9–22.4) | 2002–2017 3.2 (2.1–4.4)* | 2.7 (1.8–3.6)* |
|        | Respiratory Disease | 2000–2009 −3.8 (−6.1–−1.5)* | 2009–2017 0.3 (−2.5–3.2) | −1.9 (−2.9–1.0)* |
| All    | Trauma and Toxicosis| 2000–2002 9.4 (−20.8–51.0) | 2002–2017 −1.6 (−2.9–−0.3)* | −1.1 (−2.3–0.2) |

Statistical analysis. Grid Search Method and Permutation test were used to find the joinpoints. The log-linear regression model was used to determine the statistically significant trend change connection points in the model through Permutation test, limiting at most one trend point. Annual Percent change (APC) and average annual Percent change (AAPP) in each period were calculated. If AAPP is completely located in a single junction segment, then AAPP = APC, indicating that the data of this group generally shows a monotonic upward or downward trend. All data are expressed as percentages. The 95% confidence interval (95% CI) of APC was estimated by using the T-distribution, and the AAPP confidence interval was estimated by using the normal distribution. If AAPP was located within a single junction segment, it was estimated using the T-distribution. Statistical analysis was performed using Joinpoint Regression Program 4.7.0.0 (National Cancer Institute, NCI, National Center for Statistical Research and Application of USA) and Excel 365 software. P < 0.05 (two-sided) is considered statistically significant.

Ethical approval. This article does not contain any studies with human participants or animals performed by any of the authors.
Table 2. The trends of the top 5 causes of death in rural areas of China from 2000 to 2017. APC Annual Percent Change; AAPC Average Annual Percent Change; CI confidence interval. Significant values are in bold.

| Gender | Diseases                  | Year-range | Trends (1) APC (95% CI, %) | Year-range | Trends (2) APC (95% CI, %) | AAPC (95% CI, %) |
|--------|---------------------------|------------|-----------------------------|------------|-----------------------------|-----------------|
| Male   | Malignant Tumor           | 2000–2007  | 4.5 (2.5–6.6)*              | 2007–2017  | −1.1 (−2.2–0.1)             | 1.0 (0.2–1.8)*  |
|        | Cerebrovascular Disease   | 2000–2017  | 1.4 (0.7–2.2)*              | 2005–2017  | −1.4 (0.7–2.2)*             | −1.4 (0.7–2.2)* |
|        | Heart Trouble             | 2000–2005  | 0.1 (−3.3–5.5)              | 2005–2017  | 5.0 (3.5–6.6)*              | 3.9 (2.9–4.9)*  |
|        | Respiratory Disease       | 2000–2017  | −3.3 (−4.5–2.2)*            | 2005–2017  | −3.3 (−4.5–2.2)*            | −3.3 (−4.5–2.2)*|
|        | Trauma and Toxicosis      | 2000–2017  | −0.6 (−1.6–0.4)             | 2005–2017  | −0.6 (−1.6–0.4)             | −0.6 (−1.6–0.4) |
| Female | Malignant Tumor           | 2000–2003  | 10.7 (0.9–21.4)*            | 2003–2017  | 1.2 (0.3–2.1)*              | 2.8 (1.2–4.5)*  |
|        | Cerebrovascular Disease   | 2000–2005  | 0.7 (−4.4–6.1)              | 2005–2017  | 5.1 (3.7–6.6)*              | 4.1 (3.2–5.0)*  |
|        | Heart Trouble             | 2000–2017  | −4.0 (−5.3–2.8)*            | 2005–2017  | −4.0 (−5.3–2.8)*            | −4.0 (−5.3–2.8)*|
|        | Respiratory Disease       | 2000–2003  | −13.7 (−22.9–3.4)*          | 2003–2017  | 0.1 (−1.0–1.1)              | −2.5 (−4.4–0.6)*|
|        | Trauma and Toxicosis      | 2000–2003  | −3.6 (−4.8–2.3)*            | 2003–2017  | −3.6 (−4.8–2.3)*            | −3.6 (−4.8–2.3)*|
| All    | Malignant Tumor           | 2000–2003  | 11.4 (1.8–21.9)*            | 2003–2017  | −0.3 (−1.1–0.6)             | 1.7 (0.1–3.3)*  |
|        | Cerebrovascular Disease   | 2000–2005  | 1.5 (0.6–2.5)*              | 2005–2017  | 1.5 (0.6–2.5)*              | 1.5 (0.6–2.5)*  |
|        | Heart Trouble             | 2000–2005  | 0.1 (−4.3–4.7)              | 2005–2017  | 5.5 (4.3–6.8)*              | 4.3 (3.4–5.2)*  |
|        | Respiratory Disease       | 2000–2017  | −3.6 (−4.8–2.3)*            | 2005–2017  | −3.6 (−4.8–2.3)*            | −3.6 (−4.8–2.3)*|
|        | Trauma and Toxicosis      | 2000–2003  | −13.2 (−23.1–−2.1)*         | 2003–2017  | 0.8 (−0.3–1.9)              | −0.7 (−2.1–0.8) |

In rural areas (Table 2, Online Supplementary Figure s1), the trends of the proportions of the top 5 causes of death are all significant except trauma and toxicosis in overall from 2000 to 2017. The AAPC of malignant tumor, cerebrovascular disease, heart trouble, and respiratory disease are 1.7%, 1.5%, 4.3%, and −3.6%, respectively (P < 0.05). Stratification analysis by gender reveals that the AAPC of the proportion of deaths caused by respiratory disease from 2000 to 2017 lies entirely within a single joinpoint segment, with a declining trend and AAPC = −3.3% in males (Online Supplementary Figure s2-D1), AAPC = −4.0% in females (Online Supplementary Figure s2-D2), respectively (P < 0.05). Meanwhile, the declining trend of the proportions of deaths of trauma and toxicosis is significant only in females with AAPC = −2.5% (P < 0.05).

The combined proportion of deaths due to cerebrovascular disease and heart trouble increases (39.02% to 43.56%, P < 0.05) from 2000 to 2017, which is higher than that due to malignant tumor in overall in urban areas (P < 0.05) (Fig. 1-A1). The AAPC of the proportion of deaths of cardio-cerebrovascular disease from 2000 to 2017 lies within 2 joinpoint segments (AAPC = 1.3%, P < 0.05), with an increasing trend from 2002 to 2017 and AAPC = 1.74% (P < 0.05), (Fig. 1-A3), which is higher than that of malignant tumor (Fig. 1). The results of stratification analysis by gender is similar. In rural areas, the proportion of deaths of cardio-cerebrovascular disease increases (32.03% to 45.91%, P < 0.05) (Fig. 1-A3), which is higher than that due to malignant tumor (Fig. 1). The results of stratification analysis by gender reveals that the AAPC of the proportion of deaths of cardio-cerebrovascular disease is 2.7% (P < 0.05) (Fig. 1-A3), with a peak in females at 3.04% (P < 0.05) (Fig. 1-A3). Overall, the increasing trend of the proportions of deaths of cardio-cerebrovascular disease is steeper than that of malignant tumor, which is not related to gender (Figs. 1, 2).

Discussion

This study reveals that in China, the top 5 consistent causes of death are malignant tumor, cerebrovascular disease, heart trouble, respiratory disease, and trauma and toxicosis during the past 18 years. All these 5 causes account for 82.6% in 2000, 86.49% in 2017 in urban areas and 83.31% in 2000, 88.34% in 2017 in rural areas of the total deaths. Trend analysis results suggest that the proportions of death of malignant tumor, cerebrovascular disease, and heart trouble have significantly increased, while the one of respiratory disease has significantly decreased. The declining trend of the proportion of death of trauma and toxicosis is significant only in females. In addition, the increasing trend of the proportion of death of cardio-cerebrovascular disease is steeper than that of malignant tumor (AAPC: Urban, 1.5% vs 0.5%; Rural, 2.7% vs 1.7%), the decreasing trend of the proportion of respiratory disease in rural areas is steeper than that in urban areas (AAPC: −3.6% vs −1.4%).

Malignant tumor is the first-leading cause of death in the world. The GLOBOCAN 2018 estimated that there were 18.1 million new cases of malignant tumor and 9.6 million related deaths in 2018. The large burden of malignant tumor is projected to increase with a predicted 22 million new cases and 13 million related deaths occurring by 2030. Previous studies have identified that the malignant tumor burden is greater in higher Human Development Index countries, while a greater proportion of the global mortality burden was observed in low and medium Human Development Index countries. The proportion of malignant tumor incidence will experience a 100% and 81% increase in low and medium Human Development Index countries from 2008 to 2030, respectively. Our study estimated that malignant tumor was the first-leading cause of death in China with AAPC = 0.5% and 1.7% from 2000 to 2017 in urban and rural areas, respectively. Malignant tumor-related deaths were more popular in urban than in rural areas. Even the proportion of death caused by malignant tumor presented a continuing upward trend during the past 18 years, the one in urban areas only continuously increased.
from 2000 to 2008. In urban areas, malignant tumor-related deaths accounted for 27.12% of total deaths in 2008, and its proportion has been fluctuating at a high level from 2008 to 2017. In rural areas, even malignant tumor-related deaths only accounted for 23.07% (lower than 25.50%) of total deaths in 2017, it presented a continuing upward trend from 2008 to 2017. Based on this result, we urgently need to control its occurrence in rural areas in China, but at the same time, we should also strengthen interventions for urban populations because of their high base.

In 2016, it was reported that CVD accounted for more deaths than tumor or any other disease did in China, which was the first-leading cause of death in China. In 2018, National Center for Cardiovascular Diseases estimated that about 290 million patients were suffered from CVD in China, including 13 million from stroke, 11 million from coronary heart disease, 5 million from pulmonary heart disease, 4.5 million from heart failure, 2.5 million from rheumatic heart disease, 2 million from congenital heart disease and 245 million from hypertension. Our study indicated that the proportion of death caused by malignant tumor was higher than that caused by cerebrovascular disease and heart trouble, but lower than that caused by CVD. CVD-related deaths accounts for more than 40% of total deaths after 2010, especially in females (more than 45%), with a peak of 50.4% in rural females in 2017. Increasing aging, lifestyle changes, psychological stress, and other unhealthy behaviors have led to a continuous increase in the number of heart trouble, increasing the burden of cardiovascular disease, especially the increase in cardiovascular mortality in rural areas in China. Note that the proportion of death of heart trouble is rising fastest, especially in rural areas with AAPC = 4.3%. However, the density of health-care professionals is lower in rural than urban areas in China. So, strengthening the prevention and treatment of CVD under the leadership of the government is an urgent task, both in urban and rural areas.

According to the Global Burden of Disease 2019 (GBD 2019) study and WHO, a total number of lives lost, is associated with three broad topics: cardiovascular, respiratory, and neonatal conditions. Respiratory diseases, especially respiratory infections, and tuberculosis are closely related to economic development. People living in a low-income country are far more likely to die of respiratory diseases. With the development of the economy and the acceleration of urbanization in China, the proportion of death caused by respiratory diseases is decreasing, especially in rural areas with AAPC = −3.6% from 2000 to 2017. Moreover, respiratory diseases are also closely related to air quality. China has experienced a severe deterioration in air quality over the past several years.
However, air pollution control policies in China have been experiencing significant positive changes from 2013 to 2020, which might explain the reason why respiratory diseases have been controlled to be the fourth leading cause of death and showing a downward trend in China. Trauma and toxicosis is a significant public health problem and among the leading causes of death worldwide. It was consistently the fifth leading cause of death in China from 2000 to 2017. Road traffic crashes and alcohol use are the leading risk factors for death and disability, particularly among males in China, which contribute to health loss from many causes and exacted their toll throughout the rest of victims’ lifetime. Fall injury is a serious cause of morbidity among older people and its occurrence increases dramatically with age. China has begun the accelerated aging process. As a result, there will be more and more older people in the future, and fall injury will be an important cause of trauma and toxicosis-related death. Therefore, in order to prevent trauma and toxicosis, these interventions such as speed enforcement and drink-driving enforcement need to be strengthened.

Our study provides a chance demographically and epidemiologically for careful review of population health indicators at the national levels, which is critical for healthcare providers in China to develop evidence-based policies. The result of this study reflects both similarities and differences when compared with data from leading causes of death in the US from the years 2000 to 2017. The top 5 causes of death in both China and the US include cancer, cardiovascular disease, cerebrovascular disease. Although these top causes of death remain the same in both China and the US, the trends of those disease mortalities in China are opposite to the ones in the US. Our data show that the mortalities of cardio-cerebrovascular disease and cancer in China have been significantly increasing. However, in the US, cardio-cerebrovascular disease mortality has been steadily declining from 1999 to 2017, with changes for heart disease mortality per 100,000 from 266.5 in 1999 to 165.0 in 2017, for stroke mortality from 61.6 to 37.6, and the cancer death rate has declined by 29% from 1991 to 2017, with an average of 1.5% per year from 2008 to 2017.

The most important step in explaining the reason why the trends of death caused by cardio-cerebrovascular disease and cancer in China and the US are opposite is the examination of contributors to those mortality trends in each country. Ford et al. used IMPACT Coronary Heart Disease Model to examine contributors to the decline in coronary disease mortality rate in the US from 1980 to 2000, which shows the decreasing coronary disease mortality rate is likely attributable to a variety of factors, including improved primary health care and clinical

Figure 2. Comparison of trends for malignant tumor and cardio-cerebrovascular disease as causes of death in rural areas of China from 2000 to 2017. Note A all; M male; F female; I line chart based on raw data; 2 Joinpoints graph for malignant tumor; 3 Joinpoints graph for cardio-cerebrovascular disease; APC Annual Percent Change; AAPC Average Annual Percent Change; *Indicates that AAPC or APC is significantly different from zero at the alpha = 0.05 level. x-axis: year; y-axis: the proportion of deaths.
management, changes in risk factors, and the relative contribution of primary and secondary prevention.24. Ford et al. reported "secondary preventive therapies after myocardial infarction or revascularization (11%), initial treatments for acute myocardial infarction or unstable angina (10%), treatments for heart failure (9%), revascularization for chronic angina (5%), and other therapies (12%)"24, and "approximately 4% was attributed to changes in risk factors, including reductions in total cholesterol (24%), systolic blood pressure (20%), smoking prevalence (12%), and physical inactivity (5%)"24. In contrast, the increasing trends in the mortality rates of cardio-cerebrovascular disease and cancer in China are linked to an increased range of risk factors, including lack of evidence-based health education, unhealthy lifestyle choices, such as smoking, unhealthy diet, physical inactivity, and changes in social pressures and norms. To some extent, many of those risk factors are preventable, and some are avoidable under certain control. Therefore, the examinations of contributors to the shifting patterns of leading causes of death provide insight into the direct and indirect effects of primary health care and secondary preventive therapies on mortality.

There might be several limitations in our study. First, our results are based on a secondary analysis of China Statistical Yearbook data although the data we used came from a wide range of years from 2000 to 2017. Due to the limitations of source data, we cannot obtain data for the overall country, and the reprocessing of data cannot be further adjusted nor standardized in this study. Second, we did not analyze the determinants of the causes of death since our study is an exploratory ecological trend study. Third, the results of our study can only give the weight of different causes of death and reflect the trend of proportion since this study is based on the composition of the causes of death rather than mortality.

In conclusion, the top 5 causes of death in China account for more than 85% of all deaths in 2017. The trends of all diseases have been increasing, except for respiratory disease. Cardio-cerebrovascular disease should be the primary focus for disease prevention and control since it has accounted for the largest proportion with the steepest increasing trend during the past 18 years.

Data availability

The data that support the findings of this study are openly available in National Bureau of Statistics at http://www.stats.gov.cn/tjsj/ndsj/.

Received: 23 December 2021; Accepted: 5 May 2022 Published online: 17 May 2022

References

1. WHO. The top 10 causes of death., 2018.
2. WHO. Global Health Observatory (GHO) data., 2019.
3. Yang, G. et al. Mortality registration and surveillance in China: History, current situation and challenges. Popul. Health Metr. 3(1), 9 (2005).
4. Center PHSD. National Disease Surveillance System-Death Cause Monitoring Network Report Database. Vol. 2019, 2019.
5. China, N. B. O. S. China Statistical Yearbooks (China statistical Publishing House, 2001).
6. Kim, H. J., Fay, M. P., Feuer, E. J. & Madhune, D. N. Permutation tests for jointpoint regression with applications to cancer rates. Stat. Med. 19(3), 355–351 (2000).
7. Bray, F. et al. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J. Clin. 68(6), 394–424 (2018).
8. Ferlay, J. et al. Cancer incidence and mortality worldwide: Sources, methods and major patterns in GLOBOCAN 2012. Int. J. Cancer 136(5), E359–E386 (2015).
9. Fidler, M. M., Soerjomataram, I. & Bray, F. A global view on cancer incidence and national levels of the human development index. Int. J. Cancer 139(11), 2436–2466 (2016).
10. Bray, F. et al. Cancer Mortality and Incidence Worldwide in 2018: Sources, Methods and Major Patterns in GLOBOCAN 2018. Int. J. Cancer 144(1), 27–36 (2019).
11. Hu, S. et al. Summary of the 2018 report on cardiovascular diseases in China. Chin. Circ. J. 35(3), 209–220 (2019).
12. Li, Y. et al. Can China achieve a one-third reduction in premature mortality from non-communicable diseases by 2030? BMC Med. 15(1), 132 (2017).
13. Anand, S. et al. China’s human resources for health: Quantity, quality, and distribution. Lancet 372(9651), 1774–1781 (2008).
14. Luo, L. et al. Short-term effects of ambient air pollution on hospitalization for respiratory disease in Tiaoyuan, China: A time-series analysis. Int. J. Environ. Res. Public Health 15(10), 2160 (2018).
15. Korthoren, N., Niemi, S., Parkkari, J., Palvanen, M. & Kannus, P. Unintentional injury deaths among adult Finns in 1971–2008. Injury 42(9), 885–888 (2011).
16. Alcohol use and burden for 195 countries and territories, 1990–2016: A systematic analysis for the Global Burden of Disease Study 2016. Lancet 392(10152), 1015–1055 (2018).
17. Yang, G., Zhang, F. & Ji, L. Drink driving in the background of public health. Chin. J. Health Educ. 8, 735–737 (2013).
18. Korthoren, N., Kannus, P., Niemi, S., Palvanen, M. & Parkkari, J. Fall-induced deaths among older adults: nationwide statistics in Finland between 1971 and 2009 and prediction for the future. Injury 44(6), 867–871 (2013).
19. Vecino-Ortiz, A. I., Jafri, A. & Hyder, A. A. Effective interventions for unintentional injuries: A systematic review and mortality impact assessment among the poorest billion. Lancet Glob. Health 6(5), e523–e534 (2018).
20. Centers for Disease Control and Prevention. Underlying Cause of Death, 1999–2018. CDC WONDER Online Database. Atlanta, GA: Centers for Disease Control and Prevention; 2018. Accessed March 12, 2020.
21. Shah, N. S. Trends in cardiometabolic mortality in the United States, 1999–2017. JAMA 322(8), 780–782 (2019).
22. Surveillance, Epidemiology, and End Results (SEER) Program. SEER Stat Database: Mortality-All COD, Total US (1990–2017) <Early release with Vintage 2017 Katrina/Rita Population Adjustment> Linked To County Attributes—Total US, 1969–2017 Counties. National Cancer Institute, Division of Cancer Control and Population Sciences, Surveillance Research Program; 2019; underlying mortality data provided by National Center for Health Statistics, 2019.
23. Ford, E. S. et al. Explaining the decrease in U.S. deaths from coronary disease, 1980–2000. N. Engl. J. Med. 356(23), 2388–2398 (2007).
25. Yang, G. et al. Rapid health transition in China, 1990–2010: Findings from the global burden of disease study 2010. *Lancet* **381**, 1987–2015 (2013).

26. Wei, W. et al. Cancer registration in China and its role in cancer prevention and control. *Lancet Oncol.* **21**, e342-349 (2020).

**Acknowledgements**

This study was supported by the National Natural Science Foundation of China (Grant No. 82103935) and Young Key Teacher Funding Program of Huanghuai University.

**Author contributions**

Y.R. substantially contributed to the design and drafting of the study and the analysis and interpretation of the data. H.Z./Z.L. revised it critically for important intellectual content. All authors were involved in collecting data and approved the final version of the manuscript.

**Funding**

This study was supported by the National Natural Science Foundation of China (Grant No. 82103935).

**Competing interests**

The authors declare no competing interests.

**Additional information**

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-022-12256-8.

**Correspondence** and requests for materials should be addressed to Y.R.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. © The Author(s) 2022.